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ABSTRACT

Selections from "The Science Teacher" magazine, appearing generally between January 1970 and May 1972, are offered in this compilation. Articles are divided into four sections: (1) A Point of View--personal perspectives on the nature and scope of the environmental problem, (2) Aspects of the Problem--relevant background material, (3) Environmental Education--course descriptions and curricula, (4) Student Activities--research projects and classroom ideas, and (5) Resources for Curriculum Guiding--book reviews and notes about other available materials. Subject content is wide-ranging, from ecology, energy and power, pollution and waste disposal, health, and natural resources to urbanization, population and food supply, transportation, architecture, industrialization, and technology. The 66 articles present a variety of viewpoints about causes and solutions to environmental situations and problems and illustrate a variety of approaches that science teachers at the secondary level are using to increase student awareness of the dilemmas and some of the choices that face society today. (EL)

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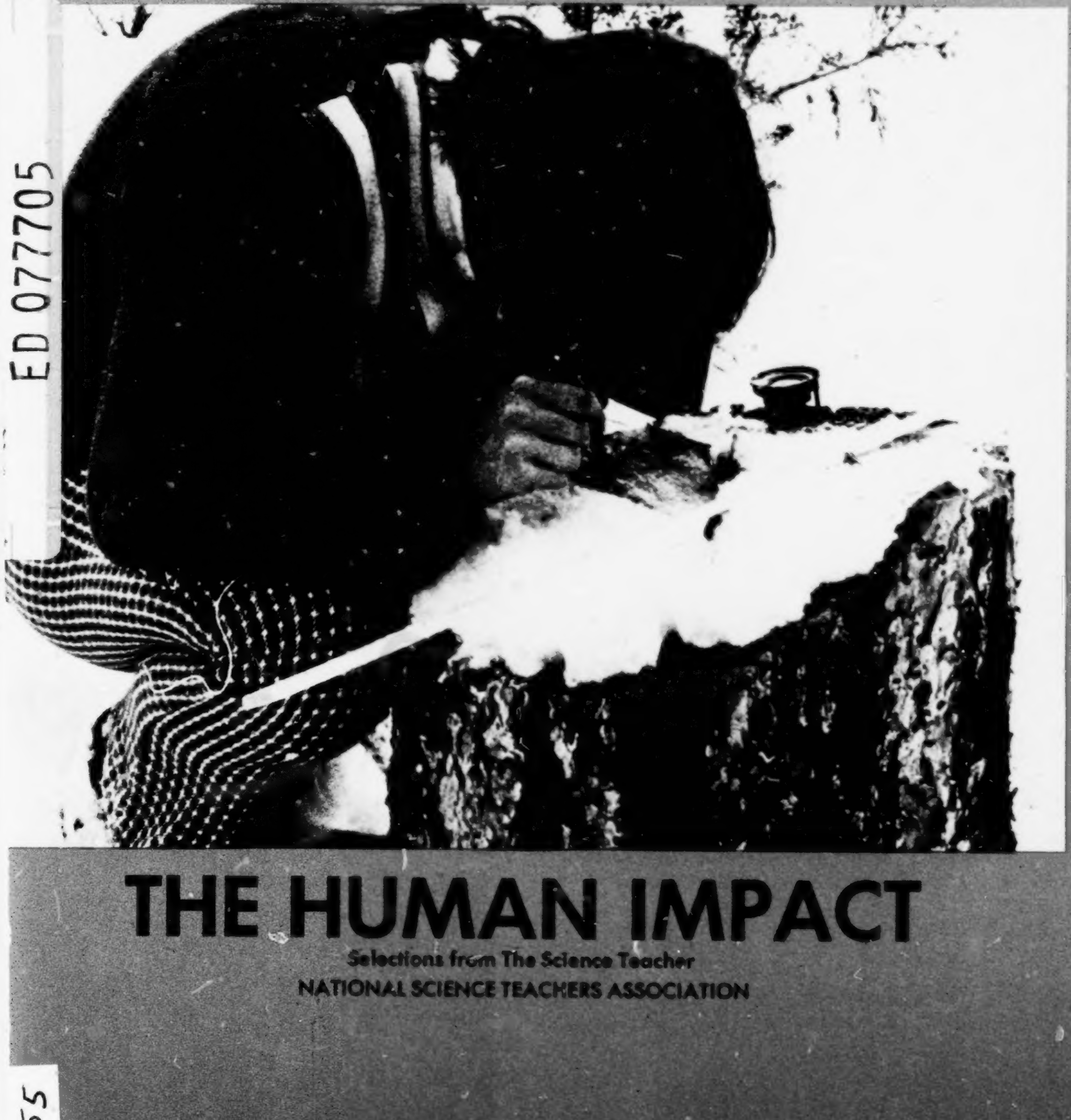

THE HUMAN IMPACT

Selections from The Science Teacher
NATIONAL SCIENCE TEACHERS ASSOCIATION

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ENVIRONMENT: THE HUMAN IMPACT

Selections from
The Science Teacher

Compiled by Rosemary E. Amidei
with assistance of
Charles L. Frederick and Robert Yager

NATIONAL SCIENCE TEACHERS ASSOCIATION 1973

PREFACE

AT THE end of the 1960s, the American public became conscious, as it had not been before, of man's impact on the environment. There had been earlier national surges of conscience—during the Conservation Movement at the turn of the century and during the Dust Bowl era of the thirties—but never before had the outcry been so widespread nor had it had the same note of desperation.

The quality of the environment is now a matter of great national and international concern. Some problems—air and water pollution, resource depletion, waste disposal—are easily identified. But causes and even the definitions of the problems themselves are not. There is great disagreement as to whether the specific problems stem basically from social institutions, population growth, selfish and competitive values, increasing technology, or simply from ignorance of the natural and social environments. Similarly, there is disagreement about the boundaries of environmental problems . . . about components . . . about interactions. Scientific questions are entangled with economic ones and these with social questions. A discussion of oil spills quickly escalates to national priorities, to moral and aesthetic values, to man's role in nature. A discussion of energy problems quickly points to the Achilles heel of our technological structure.

The articles that follow present a variety of viewpoints about causes and solutions. They illustrate, too, the variety of approaches that science teachers at the secondary level are using to increase student awareness of the dilemmas and some of the choices that face society today. One teacher, for example, helped his class to initiate a community recycling project. The entire science department of another school joined with social studies, fine arts, and language arts teachers to organize the excavation of an Indian village. Some teachers directed their students' attention to the urban scene—the weathering of buildings, the behavior of pigeons; others, to the forests and wetlands.

Regardless of the approach, however, certain themes emerge again and again. Foremost among these are the interrelatedness of the major human problems, which is reflected in the interdisciplinary nature of so many of the environmental education courses, and the importance of values in making decisions and determining solutions.

Most of the articles appeared in *The Science Teacher* between January 1970 and May 1972.* Those that appeared earlier were selected by Charles L. Frederick and Robert Yager of the University of Iowa as especially significant. In an effort to aid the reader, articles have been divided into four sections: A POINT OF VIEW, Some personal perspectives on the nature and scope of the environmental problem; ASPECTS OF THE PROBLEM, Some relevant background material; ENVIRONMENTAL EDUCATION, Course descriptions and curricula; and STUDENT ACTIVITIES, Research projects and classroom ideas. Since the articles were not written to fit specific categories, however, readers will find a good deal of overlap between sections. A final section, RESOURCES FOR CURRICULUM BUILDING, brings together book reviews and mentions of other useful resource items that will aid the teacher in assembling background and reference material. The miscellaneous items mentioned in this section were still available in January 1973.

Rosemary E. Amidei
National Science Teachers Association
Washington, D.C.

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*Authors' affiliations stand as they did when the articles were originally printed.

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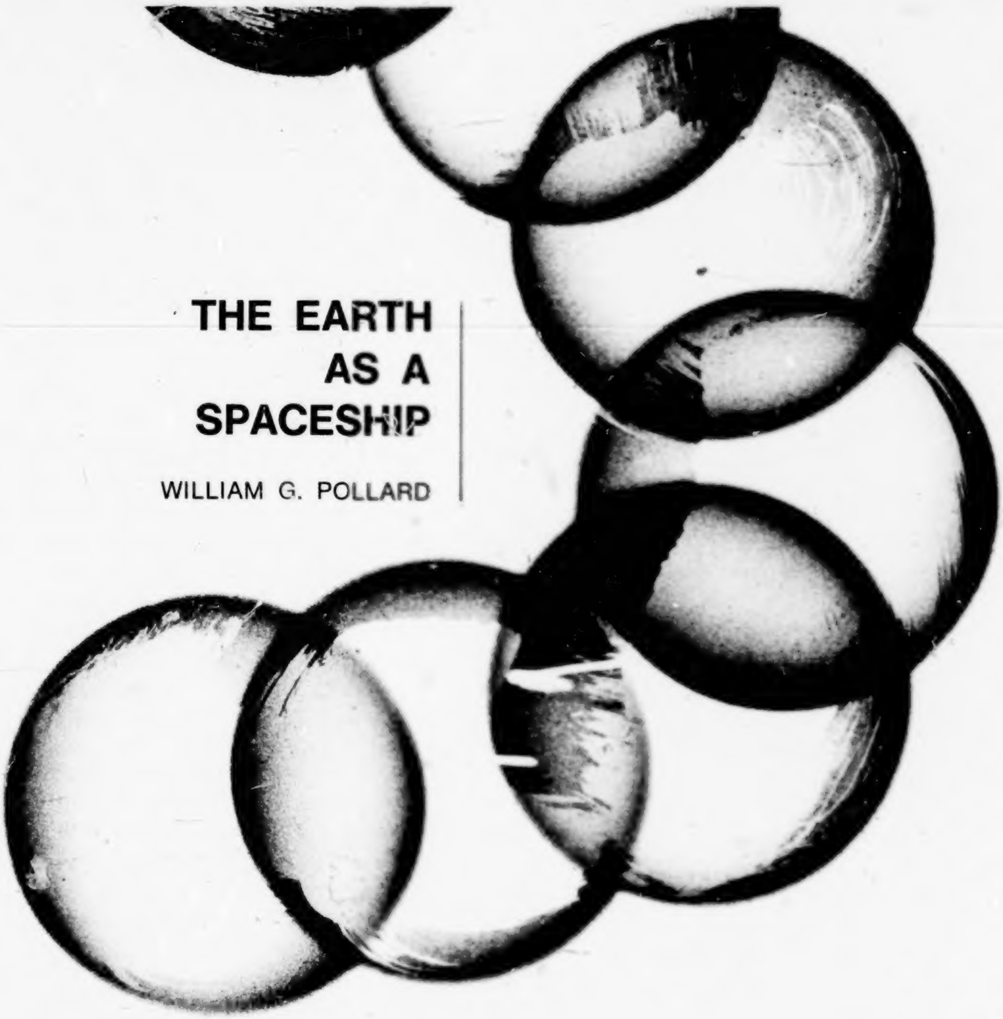
PART I

A POINT OF VIEW

Some personal perspectives on the nature and scope of the environmental problem



THE EARTH AS A SPACESHIP

WILLIAM G. POLLARD

PEOPLE all over the earth have been thrilled with the beautiful pictures of our planet sent back by television from the Apollo missions and subsequently reproduced in color from still photographs. From these we have acquired a new perspective on the earth. We all realize, as we never quite did before, how small, restricted, and limited is this ball floating out in space which is our home in the universe. In addition, the Apollo pictures have given us a fresh appreciation for the beauty of the earth in comparison with the moon and other planets. All of this has an importance for the history of man on this planet through the remainder of this century. We have reached a crucial turning point in our relationship with the earth, the nature of which it is of vital importance that all understand.

Dr. Pollard is Executive Director, Oak Ridge Associated Universities, Oak Ridge, Tennessee. This article is adapted from the series of NSTA-Sunoco science seminars presented at the annual convention of the National Science Teachers Association in Dallas, Texas, March 21-25, 1969.

This perspective is quite new in human experience. In all previous centuries of man's habitation of the planet, the earth seemed a vast unending frontier of unlimited resources. On land or sea it seemed to stretch out before man without limit. It is said that when man first appeared on the planet, God said that he would "be fruitful and multiply and fill the earth and subdue it, and have dominion over the fish of the sea, and over the birds of the air, and over the whole earth." But in any previous century the thought of man or anything else actually filling the earth would have seemed fantastic. Vast areas, even whole continents, of the earth's surface were only sparsely if at all settled by man. Man thought consciously of himself as a minority species among many others which outnumbered him. Human settlements were for the most part tiny islands in the midst of or on the edge of the great primeval forests of the earth. Man exercised a limited dominion over horse and dog, sheep and cattle. But always there was danger and uncertainty as ever-watchful tigers or wolves lurked in the shadows. Over two essential elements, the world of microorganisms and the fertility of the soil, man exercised no dominion whatever. As a result, epidemic disease, plague, and famine were ever-present threats periodically actualized in terrible scourges before which man stood helpless. Bound as man was to the earth's surface, the birds of the air remained beyond his reach. For all his cleverness as a fisherman and sailor, the sea remained a vast and alien domain in which creatures large and small disported themselves, oblivious of man and his ways. The dominion over the earth exercised by man was token and symbolic at best, and he was very, very far indeed from having subdued the whole earth to his purposes.

THE twentieth century has changed all this. In earlier centuries man had been fruitful, but he had not multiplied appreciably. At the beginning of the Christian era there were only about 300 million human beings on the earth. It required 17 centuries to double this number to 600 million. Then in 1820 the world population of species *Homo sapiens* passed the 1 billion mark. By 1930 it had doubled to 2 billion. Just a few years ago, in the early sixties, it passed 3 billion. By 1975 it will have reached 4 billion. Hereafter, if present levels of human fertility and declining death rates continue, it will reach 5 billion by 1985, 6 billion by 1993, and at the end of the century (only 30 short years from now), it will stand at 7.2 billion. The earth will then be twice as crowded as it is now. Moreover man will have effectively filled it. It will have all the human beings on it that it can support and feed at any reasonable level of quality of life.

This same century, the 20th, also saw man first realize a full dominion over the earth. There are many persons still living whose childhood was spent in the first decade of this century—before the advent of either the automobile or the airplane, before electric power, radio and TV, and great cities and highways as we know them today. In just the span of a single lifetime, today's older people have seen the whole face of the earth transformed by the phenomenon of technology. A jet flight over almost any part of the earth today provides striking evidence of this transformation. Everywhere the fields and highways, factories and cities of man stretch endlessly in every direction. The great primeval forests of the earth are rapidly shrinking and by the end of this century will have essentially disappeared. This is true not only of the developed portions of the earth—Japan, America, Europe, and Russia—but also of those areas we consider underdeveloped—Asia, Africa, and Latin America. Even where the people continue economically depressed, technology in the form of steel mills and factories, highways and airports, dams, power plants, and machinery is everywhere in evidence. In this century man has not only filled the whole planet but has subdued it as well and has taken effective dominion over every creature.

In recent years wilderness and wildlife societies have been formed with a sense of panic about them. Even in Africa, which we still think of as a continent teeming with wild and exotic animals in a natural state, the true situation is one of the rapidly approaching extinction of many species. With the best that these societies, or any of us, can do, by the end of this century the only wild animals left on the earth will be found in zoos or scattered national parks maintained by man for their protection. All the rest of the planet will be devoted directly to man and his needs: to the production of his food and of the water and energy to do his work; to his vast cities and the system of highways, air lanes, and seaways linking them together; and to his recreation and pleasures, foibles, fancies, and vanities. Occasionally he will visit a zoo or a wildlife preserve and sense the pathos of a vanished world which thrived before man took his dominion over it, and he may feel a sharp nostalgia for the earth as it was before man filled it and subdued it. Over all the rest of the earth every square inch of arable land will be devoted to human agriculture. All that grows and moves will be specially selected crossbreeds far removed from the wild varieties which once covered the earth. All that lives will be specially suited to the needs of man; any creature which fails to meet this standard will be bred out of existence. Yet this vast change in the status of living things on this planet is the work of but a single century in the whole 4,600 million year history of the earth.

Now that astronauts completely circle the earth in less than two hours, and particularly since the Apollo pictures, we no longer think of the earth as an unlimited, vast, and unending frontier. Almost universally we have come instead to think of it as a relatively small, circumscribed ball floating out in the vastness of space. We are conscious of crowding together on this ball. We have begun to worry about the extent to which we have been polluting it and exhausting its precious and limited resources. We have indeed just begun to think of it in the same way that a crew would think of its spaceship.

IT IS INSTRUCTIVE to pursue the analogy of the earth as a large spaceship. An interesting exercise is to write down the design criteria for a spaceship to carry a crew of 250 on a 40-year journey through space. Such criteria would include adequate radiation shielding; energy or fuel reserves required for instrument operation, navigation, and heating; assured supplies of air, water, and food for the crew throughout the journey; waste reprocessing and disposal; and many others. With such a list in hand, it is instructive to review the extent to which the earth considered as a spaceship, fulfills each of the design criteria. One discovers in carrying out this exercise that the earth is amazingly well designed as a spaceship for carrying a crew of some two to three billion human beings, but not many more, on a long journey through space.

It would not be possible to design a more effective and efficient radiation shield for a spaceship than the earth's atmosphere. Although transparent to light it cuts out completely all the far ultraviolet, X rays, and higher-energy radiations of outer space. The aurora borealis magnificently displays this shield in operation as it keeps all the high-energy electrons and protons which bombard the earth above 60 miles from its surface. Under this efficient shield the only radiation hazard to which we are exposed is sunburn from the near ultraviolet which does get through.

Let us now consider in greater detail some of the other fundamental requirements for a satisfactory spaceship. First, it must have an adequate source of energy to last throughout the trip. Next, it must have an adequate food supply or means of producing food for the crew. The air and water reserves in the ship must be kept pure and adequate for all needs. Wastes must be reprocessed or disposed of in ways which will not contaminate the ship. Finally, the crew must not be allowed to increase in numbers, and it must remain unified throughout the journey. Divisions into warring rival subcrews or interpersonal conflicts between crew members would be catastrophic in a spaceship on an extended voyage.

ALL these elements of a spaceship economy face us in a particularly acute form as we move into the last third of this century. Consider first the basic requirements for energy and water. These are interrelated, and the key to both is nuclear energy. As we consider the vast requirements which face us in the immediate future, it seems remarkably providential that man should have stumbled on nuclear energy and the possibility of its controlled utilization less than 30 years ago. Spurred by the terrible threat of Hitler's Nazi Germany, nuclear power was first developed for destructive uses, but its discovery has come barely in time to make our continued occupancy of our spaceship possible.

Until only a dozen years ago, man was exclusively dependent on chemical energy (with the minor exception of hydroelectric power) derived from the burning of fossilized fuels, such as coal, oil, and natural gas, with the oxygen of the atmosphere. This form of energy is exceedingly rare in the universe as a whole. Other than on the earth, there are very few spots in the entire universe where the necessary ingredients for such energy can be found. Nuclear energy, on the other hand, is universally present throughout the universe. Our sun is a natural hydrogen bomb in process of continuous explosion and so are the other so-called "main sequence" stars. Our galaxy, the Milky Way, contains some hundred billion such stars, and all the other galaxies are equally thickly populated with them. There is nothing more common or more natural and universal in all creation. In the fullness of time it was perhaps inevitable that man would come to exercise dominion over this universal element of nature as well.

The true role of nuclear energy for man becomes abundantly clear when we consider the next century. Since the earth will then be supporting a total population in excess of seven billion human beings, we are forced to contemplate a radically different world than the one we knew before the revolution in which we now find ourselves. To support such a population in a continuous and stable way will require an immense consumption of energy on a scale far greater than any we have seen so far. It will also require vast quantities of fresh water, mainly for irrigation of great desert areas of the earth not previously required for agriculture. The requirements for energy and for water can only be met with nuclear energy. We have already reached the danger point with water. It is inevitable that we shall soon see more and more large nuclear-powered desalination plants constructed along the coastal deserts all over the earth. Whether we burn the rocks (by extracting uranium for nuclear fission reactors) or burn the sea (by extracting deuterium for thermonuclear power plants), adequate reserves of nuclear fuels are available in the earth for many millenia. Coal and oil will be carefully husbanded and burned as fuel only for small mobile power systems, such as automobiles and airplanes. Nuclear power will be universally used for electric power, desalted water, and space heating. There is no other long-term alternative.

An extensive research program is now underway at Oak Ridge National Laboratory and others on methods of obtaining large quantities of fresh water from the sea by means of nuclear desalting plants. Although much development remains to be carried out, especially in scaling up the size of nuclear reactors and water evaporators, the objective of large-scale installations seems technically in sight. These installations will produce one or two billion gallons of fresh water per day at a cost comparable to that for present irrigation water, with byproduct electric power at a cost about half the cheapest available now. A few such installations along the Mediterranean and Atlantic coasts of northern Africa could convert the coastal desert into an abundant food producer in a region of the world which soon will be desperately short of food. The excess power could be used for fertilizer production and other important industrial chemical production processes. The total installation is referred to as an agro-industrial complex.

Nothing we will do in nuclear desalinization of the sea will compare, however, with the evaporative power of that natural nuclear power plant, the sun. The action of the sun generates a known supply of fresh water over the land areas of the earth of 72,000 billion gallons of fresh water per day. If all of this supply could be used for man's purposes, it would be 20 times the requirement of a world population of six billion people. It is, however, very poorly distributed for human purposes in that the limited fertile areas of the earth's land surface receive more than they need and much larger areas are left as arid deserts. An east-west continental divide running from Labrador through southern Canada to Alaska diverts a great deal of water on this continent into the Arctic Ocean through such mighty rivers as the Mackenzie and the Yukon, or into the Hudson Bay through other river systems. A similar divide on the Eurasian continent diverts great quantities of water through Siberia to the Arctic through the Ob, the Yenisei, and the Lena Rivers.

Several large-scale engineering projects are designed to capture such wasted water and divert it to arid regions for agricultural purposes. In Australia, the Snowy Mountains form a barrier to damp air coming in from the Pacific. A well-advanced project there diverts three rivers, which had been carrying water uselessly back into the sea, through tunnels in the mountains into canyon reservoirs on the other side. From there the water will generate two and a half million kilowatts as it is lowered to irrigate large areas of the arid interior. In America, the diversion of water from the Colorado through the 200-mile Los Angeles Aqueduct and the more recent 100-mile Colorado River Aqueduct not only supply the city of Los Angeles but irrigate the Imperial Valley and land in Mexico as well. The Feather River project in northern California will in time bring much more water to the dry south.

An even more ambitious plan now being given serious study would bring water from the huge Columbia River to several of the dry western states to the south. The most ambitious project of all is the proposed North American Water and Power Alliance (NAWAPA). In the East, this would divert rivers now flowing into James Bay in Canada through a navigable canal into the Great Lakes, raising their level and materially increasing the power from Niagara Falls. In the West, a series of dams, lifts, tunnels, and canals would turn water from the Tanana and Copper Rivers in Alaska and the Peace in Canada into a huge artificial lake 500 miles long in the Rocky Mountain Trench west of the Continental Divide, extending through British Columbia into Montana. From this lake, much of the states of Utah, Nevada, Arizona, and New Mexico could be irrigated, with water left over for Mexico. A similar project in Russia would divert a portion of the flow of the Ob and Yenisei Rivers into an immense lake on the Ob, the size of Italy, from which the central Soviet steppes would be irrigated.

The planetary scope of these projects gives emphasis to the spaceship character which the technology of the future will more and more take on. The water and air systems of the earth recognize no national boundaries. They belong to the planet as a whole and must be the responsibility of all mankind.

The need for water is closely tied in with the need for food. We are already running dangerously short of food for the world's explosively increasing population. The vast surpluses of grain and other staples, which have plagued our agricultural system in this country for so many years, are now gone. We will never see them again. Instead, restrictions on land under cultivation will be rapidly removed in the next few years, and the United States and Canada will be shipping greatly increased tonnages of grain and other foods to India, Pakistan, and China, and perhaps for several years to Russia as well. At the same time, extensive increases in world fertilizer production which are already under way will be accelerated, and the productivity of land in these countries already under cultivation will be greatly increased.

FOOD requirements of the developing countries are rising geometrically with the population growth. Even on the most optimistic projection of population growth, India will require in 1985 an additional production of food calories equal to 88 percent of its total consumption in 1965; Pakistan, 118 percent; and Brazil, 92 percent. For food protein the additional requirements in 1985 will be 93 percent in India, 121 percent in Pakistan, and 98 percent in Brazil of 1965 consumption. Surplus production in the United States, Canada, Australia, and Argentina cannot possibly meet such demands. In 1965 our excess grain production over and above domestic needs and international sales was 23 million metric tons. By 1985 we might, with a major effort, increase this to 75 million tons, but with real danger of depleting our precious soil resources. Probably we should not go beyond a surplus production of 60 million tons.

The magnitude of the problem we face can be seen in the following artificial example. Suppose we were to try to meet world food needs by bringing new desert lands under cultivation through irrigation. It requires about half an acre of land to produce enough food for the minimum daily requirements of one person. Since we are now adding a net increase of 70 million human beings *each year* to the world population, we would have to add 35 million acres of new land throughout the world each year for the rest of this century to keep up with food needs. This land would have to be supplied with a minimum of 30 billion gallons of irrigation water per day. This is a staggering requirement.

Many reactions to the world food crisis tend to be overly optimistic about the rapidity with which food production can be expanded. All mankind is profoundly in the debt of the Rockefeller Foundation and, more recently, the Ford Foundation for their foresight in recognizing, far in advance of most, the severity of the problem. For 25 years now the Rockefeller Foundation has been supporting programs of development of hybrid varieties suitable for tropical agriculture. A high-yield, resistant wheat developed in Mexico has resulted in a seven-fold increase of wheat production in that country between 1945 and 1965; Mexico has changed from an importer to an exporter. This wheat has proved well suited to Pakistan and India and is showing spectacular results there. The development of a new high-yield, resistant, and low-water-requirement dwarf rice at the Foundation's International Rice Center in the Philippines will be a great boon to Southeast Asia and Africa in the years ahead. A hybrid corn developed in Guatemala has been spectacularly successful in Thailand. In eight years, starting from a practically nonexistent crop, Thailand became by 1963 the fourth largest exporter of corn in the world. In all these cases at least 20 years were required, however, to develop these new varieties and bring them up to sufficient production for seed. Little else has been done in research and development for tropical agriculture. Doubtless, great strides can be made in the next 20 to 30 years, but the time scale cannot be compressed much below such a period. For the remainder of this century the tropical regions of Asia, Africa, and Central and South America will be continually on the ragged edge between staggering annual increases in food production and catastrophic famine. It is not a pleasant outlook.

ANOTHER spaceship requirement which is becoming crucial, particularly in the United States, is the necessity for adequate reprocessing and disposal of all wastes. Since the industrial revolution, we have been operating at an ever-increasing tempo on the one-pass mine-to-products-to-pollution system of production. Economic health has demanded a continually increasing Gross National Product. This requirement in turn has forced us to mine out of the earth's precious reserves, at an accelerating pace, coal, oil, ores, and other materials which are then converted in the manufacturing process into useful products along with atmospheric, water, and land pollutants in malignantly increasing quantities. We then finally junk the worn-out product in expanding city dumps, automobile graveyards, land fills, and general trash and litter. Clearly this system cannot be continued much longer. It is intolerable in a spaceship. A spaceship requires extreme measures of conservation in which everything—air, water, food, and other materials—is reprocessed in a continuous cycle within which the crew has its natural place. A continuously increasing GNP in the spaceship would be catastrophic. Pollution of any part of the system and accumulation of wastes cannot be tolerated.

In this country, air pollution, particularly in Los Angeles and New York, has become a problem of crisis proportions. The pollution of our rivers and lakes has reached such levels that vigorous national programs of control seem imminent. While New York City seeks new sources of fresh water, the Hudson River flows by it an open sewer. Lake Michigan and Lake Erie are no longer fit for recreational use and may even be poisoned beyond the capacity to support either fish or fowl. In another 20 years the same problems will have begun to plague the whole planet. By the next century rapid worldwide industrialization will have persuaded all nations that pollution is a planetary, not a local problem. The earth is, in fact, a single spaceship with a single atmosphere and a single water system. With a population over double that presently on the earth, waste reprocessing and pollution control will have become a recognized planetary necessity requiring a worldwide system of controls.

Here again the technological means for achieving adequate control of air and water purity are either available now or seem assured in the next ten years. Most of the industrial effluents now fouling our rivers and lakes could be processed with equipment already on the market to recover process chemicals and pay off the initial capital investment in three to ten years. Air pollution from industrial and utility plants can be similarly controlled, although at some additional cost. In time, fuel cells, improved rechargeable batteries, or steam power must replace gasoline for automobiles and trucks. The whole problem is now more political, social, and economic than technical. Its solution threatens deeply entrenched interests and firmly established patterns, and so will be accompanied by considerable social and political stress and strain. However, the ultimate demands of a spaceship economy will in time force a solution.

THESE PROBLEMS of energy, water, food, and waste handling arise from and are created by the explosive increase in human population. As we have seen, in the remaining third of this century man will have fulfilled the biblical injunction to be fruitful and multiply and fill the earth. An inescapable corollary of this injunction faces us now with terrible urgency. Because the earth is in fact a spaceship for man's journey, it is essential that once the earth has been filled by man, he must stop being fruitful and cease further multiplication. Moreover this must be accomplished within a generation, or certainly within no more than two generations. The children of today's college graduates must, as they approach adulthood, already have started the process which their children must complete; namely, that of separating human sexuality from procreation. All over the world this process will involve a profound religious and moral readjustment. Yet there is no viable alternative to such a transformation. What God required of man during the long centuries before he filled the earth is quite different from what He will require of man after he has done so. This seems clear enough. Once the crew of the spaceship has reached its full complement, there is an absolute requirement that it not be allowed any further increase. Yet no other requirement calls for such a deep-seated readjustment in long-established religious, moral, and social patterns, or is more resolutely resisted by mankind.

This problem of achieving a stable human population on the planet dwarfs all others in both urgency and difficulty. Yet one way or another it must and will be achieved. I am fearful that only after famines of awful proportions and their accompanying social paroxysms will sufficient pressure have been brought to bear to force men to a solution. There is no other way out. Sometime in the 21st century, and hopefully early in the century, a stable planetary population will have been achieved at somewhere between six and ten billion human beings. When this has been done, the requirements of that population for energy, fresh water, food, and pure air can and will be met, although most of the intellectual energy and scientific and technological skill of humanity will be absorbed by this task.

THE LAST, and certainly the most difficult, problem in achieving a satisfactory occupancy of our spaceship, is the requirement of unity in the crew. It is to this aspect of the problem that Barbara Ward's book, *Spaceship Earth,*[1] on this same general topic, is devoted. When we consider the vast social and political problems which presently confront mankind, the ultimate unification of man on the planet, which must somehow be achieved, seems almost unattainable. There are radical conflicts in ideology dividing the world into two vast armed camps. However, as we crowd closer together on the earth, the way must, and I feel confident will, be found for holding these ideologies in some kind of creative balance. Other tensions arising out of deep historic hurts maintain local conflicts in the Middle East, Southeast Asia, among African tribes, and elsewhere on the earth. America and South Africa are powder kegs of racial tension between white and black. Doubtless the achievement of what Barbara Ward calls a "balance of ideology" will involve paroxysms along the way of an intensity greater than any we have so far known. Each will, I believe, bring us closer to that unity which our spaceship status requires. Each of these adjustments will involve, as Miss Ward so fully describes, a move toward a "Balance of Power" and a "Balance of Wealth" in addition to the balance of ideology. All represent drastic changes in the world of warring nation states, of haves and have-nots, which we know now. Yet her searching analysis of all these problems does lead to a kind of guarded optimism about the ultimate outcome.

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[1] Ward, Barbara. *Spaceship Earth.* Columbia University Press. New York. 1966.

IN ORDER to get any reasonable notion of the magnitude of the challenge which the 20th century represents in the whole history of our spaceship, it is necessary to consider it from the perspective of the tremendous evolutionary investment which has been made in the earth and her creatures in bringing us to this present turning point. Our sun and its planets were formed together in the same process about four and a half billion years ago. At first all of the planets had dense atmospheres of hydrogen, ammonia, and methane gases. The massive planets like Jupiter and Saturn still retain this atmosphere. The smaller ones slowly lost it at differing rates through the escape of hydrogen from their weaker gravitational fields. Before this happened, however, the ingredients for life were produced on all of the smaller planets through the action of ultraviolet light from the sun and of lightning flashes in this primordial atmosphere. At the same time water and carbon dioxide were released out of the solid crusts of all the planets by volcanic activity which was much more intense then than now.

In the first two billion years of her history, the earth acquired in this way her great oceans, which, as they grew, contained amino acids, purines, pyrimidines, and simple sugars in solution. By three billion years ago these constituents had become assembled into the first primitive life forms. By two billion years ago, a variety of single-celled organisms resembling modern algae had evolved in the oceans. But for the first four billion years of earth history all life was confined beneath the surface of the oceans where it was protected from the fierce ultraviolet radiation of the sun. The earth was bathed in a dwindling atmosphere, reduced mainly to nitrogen gas with growing amounts of free oxygen released from carbon dioxide by photosynthesis in the teeming life in the sea.

In the meantime, Mars, being much smaller and lighter than the earth, lost this original atmosphere much more rapidly. Perhaps for a while, a billion or so years, it, too, had thin oceans and a preliminary development of life within them. But even they, too, in time evaporated and escaped. For the past two billion years or so, Mars has been dry and desolate like the moon and without an appreciable atmosphere of any kind. Closer to the sun, Venus may have had some liquid water for a short time but not long enough for any appreciable amount of carbon dioxide to be converted to solid carbonates. In the end it lost essentially all of its water and ended up with a thick atmosphere of carbon dioxide and nitrogen. It is a dense atmosphere producing a pressure at the surface 40 to 60 times greater than that on the earth. Under this heat-trap blanket the surface temperature is 800° F or more, hot enough to melt lead.

People talk very lightly these days about the prevalence of planets like this earth which could support life over a span of billions of years. When they do so they inadvertently trap themselves, it seems to me, into a set of attitudes which prevents their appreciating the earth. There are doubtless many stars with planetary systems in our galaxy. But it must be equally true that the vast majority of planets end up like Mars or Venus or Jupiter. We do not know all the conditions a planet must satisfy to permit the retention of oceans of liquid water for billions of years while allowing the escape of the primordial atmosphere of ammonia and methane in time for a nitrogen-oxygen atmosphere to replace it. But these conditions must be very stringent indeed. I doubt that there is another place like the earth within a thousand light years of us. If so, the earth with its vistas of breathtaking beauty, its azure seas, beaches, mighty mountains, and soft blanket of forest and steppe is a veritable wonderland in the universe. It is a gem of rare and magic beauty hung in a trackless space filled with lethal radiations; it is accompanied in its journey by sister planets which are either viciously hot or dreadfully cold, arid and lifeless chunks of raw rock. Earth is choice, precious, and sacred beyond all comparison or measure. The crews of the Apollo missions felt this very acutely as they compared the gray desolation of the moon below them with the distant sparkling white and azure ball in space which they had so recently left.

For most of its history the earth had no concentrated bodies of rich ores. Slowly, over billions of years, two processes working alternately produced them. One is the steady accumulation of radioactive heat deep in the earth's crust, erupting from time to time in great mountain-forming upheavals with volcanoes and earthquakes. In between these geological revolutions, wind and water worked a slow erosion back to flat plains and swamps. Throughout these changes, alternating solution and precipitation, melting and recrystallization, concentrated one compound here and another there in the earth's crust. It is necessary to know that the rich bodies of copper and tin, of iron and uranium, of gold and silver, which we so recklessly gouge out of the earth took a billion or more years to be concentrated there. They should surely not be squandered in a single century.

THE EARTH was already four billion years old when a major turning point in her long history took place. An appreciable amount of oxygen had accumulated in the atmosphere which by then was already much as it is today. From this oxygen an ozone layer was formed in the upper atmosphere which effectively shielded out the ultraviolet radiation from the sun. Following a period of geological upheaval about 600 million years ago, the earth entered a long placid epoch in her history called the Cambrian. During it a vast elaboration of multicellular organisms took place. This proliferation of living things produced great coral reefs, a profusion of sea animals called "trilobites," and the first fish. In another 300 million years the land had become clothed with vegetation and many insects had evolved. But at that time—when the earth was already 4,300 million years old—there was not a particle of coal, a drop of oil, or a bubble of gas anywhere in the crust. These great reserves of fossil fuels were laid down over the next hundred million years.

Beginning 200 million years ago, this period was followed by the age of the great dinosaurs, and then, beginning 70 million years ago, by the age of the mammals. When that age ended, just 2 million years ago, the scene had become very familiar. As yet there were no men on the earth, but all across Europe and Asia, the Americas and Africa, there were dense forests and fertile steppes clothing the earth in a blanket of green. Throughout this lush verdure were myriads of antelopes and zebras, cattle, horses and buffalo in herds, deer, tigers, wolves, and badgers all similar to those today. A remarkable planet, a tiny island in the midst of vast reaches of an alien space, had brought forth a magic garden, a teeming wonderland, maintained by a fragile balance of light and heat and gravity. A being like an angel or a demon exploring our portion of the galaxy would react with stunned amazement and delight on reaching such a spot in space, so unlike the myriad other planets he had visited.

Two million years ago, which is practically now in a 4,600 million year history, a new geologic epoch called the Pleistocene began. It is now clear that this was the most fateful and decisive moment in the whole long history of the earth. The reason is that the mysterious creative drive in the evolutionary process began then to produce man. The process unfolded in several stages and did not reach our species, *Homo sapiens*, until just some 40 thousand years ago. Man's presence did little to alter the tranquillity of the earth until quite recently. It was only 10,000 years ago that man first began to practice agriculture and build permanent villages, and only 5,000 years ago that the first civilizations emerged. But from the moment of his creation the potential was there for a drastic change. This strange new creature would in time fill the earth and subdue it and take dominion over all creatures.

The anthropologist Loren Eiseley looks back on this moment as one of dark foreboding for the earth in her beauty. With the first emergence of man, a small dark menacing cloud appeared on the horizon of time. A black hole opened in nature. A dreadful black whirlpool appeared which has been growing and turning faster and faster ever since. In his words:

> It is with the coming of man that a vast hole seems to open in nature, a vast black whirlpool spinning faster and faster, consuming flesh, stones, soil, minerals, sucking down the lightning, wrenching power from the atom, until the ancient sounds of nature are drowned in the cacophony of something which is no longer nature, something instead which is loose and knocking at the world's heart, something demonic and no longer planned—escaped, it may be—spewed out of nature, contending in a final giant's game against its master.[2]

By the end of this century the earth will be really *full* of men. But worse, it will have already been subdued and despoiled by man. All over its surface his sprawling cities will pollute the landscape. Without limit in every direction the fields and factories of man, his highways and bridges and power lines, will cover the earth. All of the gold, much of the rich accumulations of copper and tin and many other metals, will have been gouged out of the earth and squandered. By that time, nearly the total supply of oil and gas, so painstakingly accumulated and stored in the earth 200 million years ago, will already have been drawn out and burned. Most of the strange and lovely species of animals and birds with which man so recently shared the adventure of life will have become extinct. A few will remain in national parks and zoos maintained by man in his nostalgia for a lost paradise. His great rivers and lakes will all have been fouled, and the atmosphere above him will reek with the vast outpouring of offal from his cities and factories. The earth will have been transformed by man. Never again as long as man remains on the earth will it have anything like the wild and lovely blanket of lush verdure which so recently graced it.

THERE is increasing emphasis, as indeed there must be, on programs of conservation, control of pollution, urban renewal, and environmental health. The concern of all nations with these problems must be greatly intensified in the years ahead. Yet the very words used to describe these programs point to their complete man-centeredness. They are described and conducted solely in the interests of man and his welfare. In order to become truly effective they must, I am convinced, all be given an added dimension. We must see them all in terms also of the earth and her welfare. The earth in all her beauty is our mother. She bore us. When we pour filth into her atmosphere, befoul her lakes and rivers, disfigure her landscape with our junk piles, and recklessly squander her precious resources we desecrate her as well as endanger ourselves and our own interests. The earth has an integrity of her own independent of us. No single species she has produced in her long history has a right to destroy her and her other creatures. We need to develop a healthy and holy fear of doing so.

If man in some super-mad moment should destroy himself in a vast nuclear holocaust, one could perhaps say that it would serve him right. The rest of the universe could do without such a creature in the future. Yet such a thought immediately suggests another. For man and his destiny are inextricably linked to the earth. In destroying himself he must inevitably destroy much of the earth with him. It is a sacrilege of awful proportions to desecrate and despoil such a place with its long evolutionary investment and immense evolutionary potential. In the realm of reality transcendent to space and time such an act would not likely be easily forgiven.

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[2] Eiseley Loren. *The Firmament of Time.* Atheneum, New York. 1962. p. 12.

A number of years ago I had the privilege of reviewing a book, *Tomorrow is Already Here*, by the Swiss journalist Robert Jungk. The book was not well received, and it is my impression that it did not do very well. Several people took vigorous exception to it and to my review. No doubt the picture it presented of America was overdrawn and one-sided as these objectors claimed. But I was convinced then and am even more persuaded now that there was a disturbingly valid element of truth in that picture. The book has stayed with me, hauntingly, ever since. One quotation from the introduction will give an idea of its contents and purpose:

> America is striving to win power over the sum total of things, complete and absolute mastery of nature in all its aspects. This bid for power is not directed against any nation, class or race. . . . The stake is higher than dictators' seats and presidential chairs. The stake is the throne of God. To occupy God's place, to repeat his deeds, to re-create and organize a man-made cosmos according to man-made laws of reason, foresight and efficiency: that is America's ultimate objective. Toward this her chief efforts are directed.
>
> This is a revolution as convinced of its successful outcome as any other revolutionary movement. . . . It destroys whatever is primitive, whatever grows in disordered profusion or evolves through patient mutation. What it cannot observe and measure it subdues indirectly to its power. It says the unsayable. It knows no awe.[3]

It is this absence of awe, of any sense of the sacredness of nature, that is terrifying. It is this that drives the whirlpool. Loren Eiseley tells of a conversation he had with a young man who, as a solution to overpopulation, wanted to eventually kill off everything else so that we could live here by ourselves on synthetic food and with more room. Commenting on the colossal insensitivity of this new asphalt animal, Eiseley says: "For him there was no eternal, nature did not exist save as something to be crushed, and that second order of stability, the cultural world, was, for him, also ceasing to exist."[4] It is an appalling thought to conceive of a future world made up of such men. □

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[3] Jungk, Robert. *Tomorrow is Already Here.* Simon and Schuster, New York. 1954.

[4] Op. cit. p. 128.

SCIENCE AND SOCIAL ACTION

Barry Commoner

IN THE nine years since I last spoke to this organization, we have all become familiar with DDT, PCB, NTA, and many other letters that were just coming into our ecological consciousness in 1963. Tonight, I want to go a step further than a recitation of ecological sins, and connect science with social action. The ecological problems which we now all recognize will be solved and can be solved in a democratic way only by means of social action, by society as a whole, not by scientists.

Science is, after all, a subsidiary part of society. We tend to get a little arrogant sometimes and to think that science is a force unto itself, that we are training priests, rather than public servants. On the contrary, we teach only a part of human experience, science, and our students, and we ourselves, are a subsidiary part of society. Nevertheless, science does have a very special role. It is designated by society to report on what is happening in the world, to Nature, to people, and to the relation between them.

Today what we have to report is very grim. My own city, St. Louis, has degenerated physically in the 25 years that I have lived there. I have seen entire neighborhoods boarded up, the buildings destroyed, the people out of work, the children suffering from lead poisoning. Here is a magnificent human association, a city, literally falling apart before our eyes. All of you have seen the same thing. Consider, too, the more esoteric signs of degradation: The air is a burden to breathe, the water is foul,

Dr. Commoner is the Director of the Center for the Biology of Natural Systems, Washington University, St. Louis, Missouri. This article is a condensation of his banquet address at the 1972 NSTA convention in New York City on April 9.

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"One of the most important changes in agricultural technology . . . has been in the use of nitrogen fertilizer. In the United States generally, since World War II, nitrogen fertilizer use has gone up 12 to 14 fold. What happens when this increase intrudes upon the nitrogen cycle?"

the soil is being destroyed, the food we eat is less nutritious than before, the necessities of life are becoming adulterated. Have you gone down the supermarket shelves lately and looked at the fruit juices? Most of them are now called "fruit drinks," not juices. A "drink" is a juice adulterated with water, among other things. Have you asked any poor families whether they are now feeding their children the same volume of "drink" as they did juice? Is this one reason why the vitamin intake of the average U.S. citizen is declining?

We are destroying—physically, biologically—the habitat in which we live. Obviously there is something exceedingly wrong in our society. Most of us feel that something has to be done—not understood, not spoken about—but *done*. But if we would act successfully we must understand the origin of our present predicament.

Within the last two to three decades we have experienced an order of magnitude increase in environmental degradation. In 25 years in St. Louis I have seen the bowl of air pollution from the basin near the river extend westward block by block. I can remember the day last summer when photochemical smog spilled over into the suburbs and began to attack the pines in the area between my home and my lab.

Generally, there has been about an order of magnitude increase in the emission of pollutants since World War II. This date is an interesting one. We have all taught about the great scientific revolution of the 20s and 30s; about modern physics, theoretical chemistry, and new developments in biology. At about the time of World War II much of that abstract knowledge was converted with dramatic suddenness into practical technologies in industry, agriculture, communication, and transportation. The esoteric experiments of physicists were converted into nuclear bombs and nuclear reactors; DDT was taken off the shelves and used to kill insects; synthetic chemistry produced plastics, fibers, rubber, and detergents. This sudden change in the nature of our technology has had enormous effects—including serious pollution of the environment.

IN agriculture, we have experienced a revolution in this country. The corn yield in the Corn Belt has increased about two and one-half fold in the last 25 or 30 years. This has had great social and economic consequences, including migration to the cities of rural residents who are no longer needed on the farms. Of course, there has been an environmental impact as well. One of the most important changes in agricultural technology, for example, has been in the use of nitrogen fertilizer. In the United States generally, since World War II, nitrogen fertilizer use has gone up 12 to 14 fold. What happens when this increase intrudes upon the nitrogen cycle? The nitrogen cycle goes like this: crops contain organic nitrogen; cattle eat the crops, converting the nitrogen in the corn or the grass into cattle nitrogen; manure, containing nitrogen, is delivered to the soil and there converted by indigenous microorganisms to soil humus, organic matter from which other microorganisms release inorganic nitrogen which then is taken up by the crop. This is a nice self-contained ecological cycle. But that's not the way it happens any more in the Midwest.

For example, Illinois has no cattle to speak of. It produces corn to be shipped to Iowa and Nebraska where cattle are collected in huge feedlots and fattened for the market; their manure is deposited right there, and the cycle is broken. Often manure washes into streams and pollutes them. Meanwhile back on the farm the nitrogen is not being returned to the soil; fertilizer is used instead, and, as a result, the humus content has gone down to half of what it was in 1880. Humus is responsible for the porosity of the soil, and this porosity is what lets oxygen reach the roots. Oxygen is needed to produce the metabolic energy which roots must use to work against the diffusion gradient and take nutrients into the plant. Hence, the result of losing humus is that fertilizer is taken up less and less efficiently. So we keep piling on more and more fertilizer, raising the crop production rate, but adding more and more nitrogen that is unused by the crop, but has to go somewhere.

In 1947 the United States used 11,000 pounds of nitrogen to produce one USDA crop unit (an index of crop production, the closest available measure of what we call the biomass, or the actual amount of organic matter). In 1968 it took 55,000 pounds of nitrogen to produce the same amount of crop. The efficiency with which we used fertilizer has gone down five fold. Where is the rest of the nitrogen? Most of it drains off into streams and lakes. One result is that in a town like Decatur, Illinois, every spring for the last five or six years, the nitrate levels have been at or over the Public Health Service limits. Why is there a Public Health Service limit for nitrate concentration in water? Nitrate is readily converted to nitrite, particularly in the digestive tract of infants. Nitrite is poisonous because it combines with hemoglobin and hinders it in carrying oxygen.

If we ask agronomists why these changes were made, they will often say that they were necessary in order to feed the hungry people of the world and of the United States. But has food production really increased that much? Are we all so much better off? The data in the *Statistical Abstract of the United States*[1] show that since 1947 there has been only about a 10 percent increase in the per capita production of food in the United States. We have been exporting only about 15 to 20 percent of our production. The growth of our production has just kept up with the growth of the population. One result is that we have retired land from agriculture helped by government inducements in the form of Land Bank payments.

Why did this all come about? Quite simply, it is because it is now impossible for a Midwestern farmer to break even economically without using so much nitrogen fertilizer that water pollution is inevitable. The yield of crop with increasing fertilizer tends to level off; so to achieve the last 10 to 20 bushels of corn per acre, it is necessary to double the nitrogen input. This is an efficient way to feed the plant, but that last 10 or 20 bushels is often the difference between profit and loss to the farmer. The tragic fact is that we have forced farmers into an economic position which requires that they assault the environment in order to survive. If you look at any environmental issue, and carry it back step by step to its beginning, you will discover that it originates in a very basic *economic* issue.

ANOTHER example is soap and detergents. Before World War II we all washed ourselves with soap. Now 70 to 80 percent of cleaners are detergents (synthetics) not soaps. Why did this come about? Detergent manufacturers say there isn't enough saponifiable fat available to produce soap. However, if we again turn to the *Statistical Abstract* we discover that we are now exporting enough saponifiable fat to make up the whole deficit. So that's not the cause.

Detergent manufacturers will also tell you that detergents are better for washing-machines. Detergents suspend the dirt, while soap tends to leave dirt in particulate form. These particulates can be washed away, but they are particulates. The difficulty here is the design of washing machines. The old washing machines, made when soap was used, very often had two basins. Clothes were washed in one, lifted out, and put in the other one to rinse, leaving the dirt particulates behind. In the modern washing machine the clothes

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[1] 1970 U.S. Department of Commerce. Available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D. C. 20402.

"There is a lot of talk now about dwindling fuel resources and about capturing solar energy. Soap is a natural scheme for capturing solar energy and we have thrown it away in favor of burning petroleum to produce detergents."

are used as a filter for the dirty water in the rinse cycle. The clothes sink to the bottom or the sides, while the basket spins, and dirty water is pushed out through the clothes. That won't work if the dirt is in a particulate form, but is feasible if the dirt is solubilized. When detergents were invented, it was possible to redesign the washing machines so that now they are built to accommodate synthetic detergents rather than soap.

But, why detergents? Pound for pound, the profit derived from manufacturing detergents is nearly twice the profit derived from manufacturing soap. The development of detergents represented a forward economic step for the soap and detergent industry—it increased profits. Simultaneously, it reduced labor input because on-line production is more feasible with detergents than with soap. Soap is more amenable to a batch process method because, among other reasons, fat characteristics vary from batch to batch. Thus, soap needs closer watching. In a low-labor-input situation, detergents work out better.

But detergents are ecological idiocy! Let us look at their record. First, the manufacturers made non-degradable detergents. The molecules were branched, so the bacteria of decay that normally degrade organic materials in surface waters wouldn't break them down. Then, because of the resultant mounds of suds, manufacturers stopped making that kind of detergent and instead gave us a straight-chain detergent, still with a benzene ring on the end. Bacteria degrade detergents by lopping off carbons down the chain, ultimately leaving the benzene ring free. This may be oxidized in the water to become phenol, a toxic substance. There is some debate about how much phenol is formed; but however much it turns out to be, it still really doesn't make sense to put into the water something that *can* be converted into phenol. Phosphates, too, were put into detergents, and that story is well known.

Aside from all that, there is an ecological error in the use of any synthetic material to substitute for a natural one. One illustration of this is the use of energy. Energy is very difficult to come by. For example, fat, which is the base for soap, represents, so to speak, congealed solar energy. Solar energy is free. Taken up by the plants and the animals that eat them, it provides the raw materials for soap at low temperature with no smoke, no noise, and no depletion of fossil fuel resources. The synthetic detergent, on the other hand, must be prepared from a nonrenewable resource. It is processed at high temperatures at the expense of depleting fuel resources, and of air and water pollution. The fuel used to produce fat for soap is the sun, which comes up every day. There is a lot of talk now about dwindling fuel resources and about capturing solar energy. Soap is a natural scheme for capturing solar energy—and we have thrown it away in favor of burning petroleum to produce detergents. Similarly, cotton is a scheme for capturing solar energy that we neglect in favor of synthetic fabrics.

THROUGHOUT all of our productive activities, a series of technological transformations has taken place. Soap has been displaced by detergents; cotton and wool by synthetics; steel and lumber by aluminum; railroads by trucks; labor by automated machinery; land by fertilizer. Each one of these changes is driven by a very simple feature of our society, namely, that people manufacture or produce those things that maximize profits, by whatever method maximizes profits most. Each one of the new products or new technologies is more profitable than the one that it displaced. And in each case the new technology is much more of a threat to the environment than what it displaced. It would be a valuable exercise for high school students to trace such changes through data available in the *Statistical Abstract* and in the *Census of Manufacturers*.[2] A good topic is the truck-railroad displacement. What do we get out of freight? The delivery of something we want. It doesn't make any difference to us whether it comes by truck or rail—what we want is the ton-mile carried. But it takes six times as much fuel to move a ton-mile by intercity truck as it does by railroad. It takes four times as much energy to lay down the roadbed for a truck as it does for the railroad. The highway takes a 400-foot right of way, and the railroad a 100-foot right of way. It is ecologically insane to replace railroads with trucks, but we did it. Why? Because truck freight is more profitable. We are in ecological trouble because of our economic interest in raising or maintaining rates or profit.

WE now come to the question of what to do about these issues—which, despite their scientific background, are clearly not scientific issues, but social ones. Let's consider some alternatives.

If in 1947 we had decided that we wanted to control pollution and keep it at the 1947 level, we could have embarked upon a campaign for a 30 percent decrease in the amount of pollutant emitted per unit good produced. Had we succeeded, we would now have the same general environmental situation that we had in 1947. Alternatively we could have decided to keep the pollution level constant by controlling the size of the population, rather than by improving the technology of production. Had we allowed our technology to change as it did—generally to become an order of magnitude worse in pollutant emission than it was in 1947—but reduced the United States population by 86 percent, we would also have now the same essential environmental situation that we had in 1947. In other words, the alternatives faced in 1947 would have been to achieve the same result with either an 86 percent reduction in population or a 30 percent improvement in technology in order to keep the levels of pollution unchanged.

But the improvement in technology would involve some important economic changes. The whole pollution issue represents an enormous debt to nature which we have been accumulating, and that someone is now going to have to pay. Here, one quickly comes to the realization that the environmental issues are issues of social justice—justice for workers who may be displaced if plants close down because it is uneconomical to run a non-polluting plant, justice for citizens in the polluted areas. An examination of environmental issues leads directly to fundamental political, social, and economic difficulties. These are the issues that we must face if we are to survive the environmental crisis.

On the other hand, we, as scientists, must not confuse scientific and political issues or try to convert one to the other. A case in point is the present discussion of population control in the world. The view of the population increase as an exponential growth phenomenon is highly simplistic. Furthermore, it is a view which fails to reflect what we know about the behavior of human populations. Just ask yourself: Where in nature is there an example of an ever-rising exponential curve? There isn't one. An exponential growth curve indicates a lack of coupling to the environment. Is the human population uncoupled to the environment? Of course not. People aren't stupid. In a primitive society where food is the limiting factor, people know that you die of starvation if there isn't enough food to go around; a system of taboos and other social practices evolve, resulting in the control of population growth. Demographers tell us that in every Western country, as the standard of living has increased, people have lost the motivation for having large families. Human beings translate a rising standard of living into a self-motivated control of their own fertility. This is even happening in the Third World today.

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[2] U.S. Department of Commerce, Washington, D. C.

"We are in ecological trouble because of our economic interest in raising or maintaining rates or profit."

The birth rate is still high, but in a number of places it is dropping. To extrapolate into the future you must look at both the direction of the curve and its slope.

The point I am making here is very simple. At the least, an objective scientific examination of the population question would hold that there are two alternate ways to regulate population growth. One is enforced population control. The other is raising the standard of living. These are both *scientific* statements. However, the choice between them is not at all a matter of science, but of morality, social justice, and politics. To pretend otherwise is to hide a political issue behind a scientific cloak.

A VERY interesting example in a similar area is the recent report on growth published by the Club of Rome.[3] What this represents is a computer analysis of the relationship between various factors—population, food, and so on—in the future. Past trends were used as a basis for extrapolation. If you look at the curves you will find that the authors accepted curves which can be changed by the stroke of a pen. For example, the relationship between pollution from feedlots and the production of beef is one that could be changed tomorrow if the government would abolish Grade A beef. Feedlots produce Grade A beef; if Grade A beef were no longer sold at a premium price, the feedlots would go. In *Limits to Growth* a hypothesis about growth has been put forward which excludes the alternative of solving the problems by social action. The result says: Horrors! if we don't reduce the population, all hell will break loose. The alternative of, for example, abolishing the profit system isn't mentioned. Yet that is an alternative which might allow us to develop ecologically sensible technologies rather than ecologically foolish, but profitable, ones. The people have to decide among these alternatives. A scientific exercise can readily obscure the possibility of such a decision by wrapping it in a political assumption. Then the people get a finished product without knowing that they have a choice to make. The public has been deprived of the right of conscience.

The environmental crisis, carried to its origins, confronts us with longstanding questions of social justice. How can you discuss environmental issues in the classroom without raising the questions of racism, unemployment and profits, or the question of the war in Vietnam? If you start talking about herbicides, you end up with herbicidal warfare in Vietnam. If you talk about phosphate pollution, you will have to discuss the high rate of profit in the chemical industry.

This is a responsibility that we must face. The people who have to decide—your students and their parents, and society as a whole—simply can't get this kind of information unless you and I and the rest of the academic community help bring it to them. The ecological victories which have been won thus far have been achieved by getting the facts to the people, who have then understood that there *is* an issue. What impresses me about the recent history of the environmental issue is that the people of the United States and in most countries of the world have consciences that are ready to work on it. The people are ready to act. What they need are the facts. They don't need to be told what to do—to favor population control or improved living standards, to support the profit system or oppose it. They will be able to decide for themselves. As scientists and teachers we must be willing to educate the people and to have faith in their wisdom; to believe that the people, thus informed, will choose a humane course toward survival. ☐

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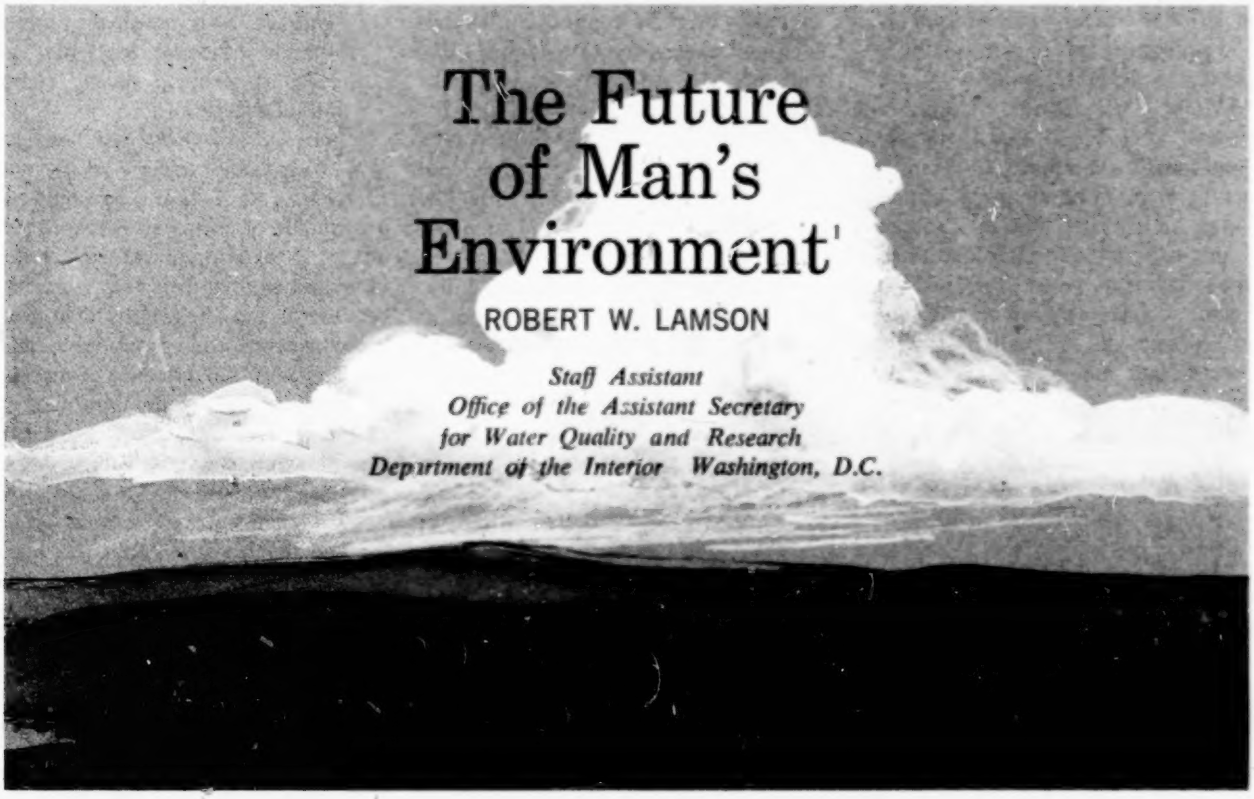
[3] *Limits to Growth.* Donella H. Meadows, Dennis L. Meadows, Jorgen Randers, and William W. Behrens III, Potomac Associates, Inc., Washington, D. C. 1972. (The authors are researchers at Massachusetts Institute of Technology. The study was sponsored by the Club of Rome and the Volkswagen Foundation.)



The Future of Man's Environment[1]

ROBERT W. LAMSON

Staff Assistant
Office of the Assistant Secretary
for Water Quality and Research
Department of the Interior Washington, D.C.

IN THINKING about and acting to influence man's future environment, we must consider many factors—the physical, biological, and social; the "man-made" as well as the "natural." Man's future environment will include the human populations, the cities and institutions which man has created, as well as the physical, chemical, and non-human biological systems—the oceans, continents, river basins, and the populations of various species of plants, fish, insects, birds, and animals upon which man depends for his survival and well-being.

If we wish to protect and improve the social, physical, and biological aspects of our environment, we must attempt to answer and act upon the answers to the following three critical questions:

- What are the trends which are helping to modify or create the natural and man-made environments which man will inhabit during the next half century?
- What is the possible range of these alternative future environments?
- What might be done to influence these trends so as to shape the future in desired directions?

This article discusses these questions, specifically as they concern the United States.

Trends and Conditions Confronting the United States

Important trends which will affect man's future environment include population growth and distribution, resource supply and use, output of wastes, and growth and use of technological and organizational power.

Population growth and distribution. The current world population of about 3.5 billion could double and reach 7 billion or more by the year 2000 if current trends continue. Projected United States population for the year 2015 ranges between 325 and 483 million. In just 50 years, the nation's population could grow by 125 to 280 million over today's population of about 200 million.

Throughout the world, people have been moving from rural areas to more densely populated urban areas, and in the United States, a very large percentage of the growing population lives and is projected to live on a very small percentage of the land.

Supply and use of resources. The United States contains a supply of renewable and non-renewable natural resources which is not unlimited, which can be depleted, but which can also be expanded and upgraded through application of scientific research, and used more efficiently through better management.

Use of many resources in the United States is projected to increase even more rapidly than population, due to increased per capita demand for resources caused by increased industrialization and use of technology, urbanization, rising levels of income and individual expectations, increased leisure, and outdoor recreation. Increasing demand for resources sometimes involves a requirement for higher quality resources, for instance, water.

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[1] This article represents only the views of the author and not those of the Department of the Interior.

Output of wastes. Output of wastes—solid, liquid, and gaseous—is increasing for the nation and per capita, thereby intensifying the threat of pollution to our air, land, and water. Sources of pollution include cities, industries, farms, heat from power generation, automobiles, recreation, mining, boating, and commercial shipping. The types, sources, and amounts of wastes will tend to increase with the growth of population, industry, and use of technology and resources. Many types of wastes are also projected to increase more rapidly than will population.

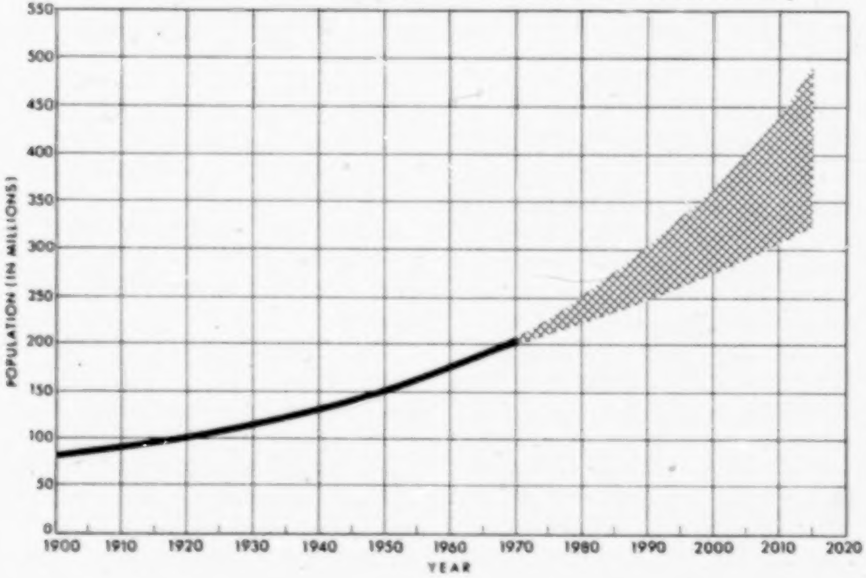
The factors which help to increase demands for resources, for clean water, pure air, and unlittered land, also help to increase the output of wastes, thereby making demands more difficult to satisfy. While we have placed increasing demands upon the environment, we have also increased our dumping of wastes into it.

Although we may not be in immediate danger of exhausting our supply of many types of resources, we are in danger, because of declining quality, of jeopardizing our usable supply.

Growth of technological and organizational power. By applying our knowledge and experience to solve practical problems, we are increasing our technological and organizational ability to:

1. Push back many of the constraints of nature, of distance, time, and disease, and of our formerly low capacity to manipulate the environment;
2. Shape and create widespread, intense, and long-lasting changes in the natural environment; some of these changes could be irreversible and adverse to man's long-term survival, health, and well-being;
3. Create "artificial" or man-made environments (for instance, cities and manned satellites), and to live in new environments (under the ocean and on the moon);
4. Perceive, predict, and monitor as well as to control, influence, or manage environmental changes, for example, via new techniques (systems analysis), tools (microscopes, telescopes, satellites, and computers), laws (domestic rules as well as international agreements concerning conservation, use of resources, and technology), and institutions (river basin commissions);
5. Increase rapidly the production of food and energy, transform raw materials into finished products through industrial processes, and transport people, goods, energy, and information.

Estimates and projections of the population of the United States, 1900 to 2015. The figures relate to 50 states in all years and to armed forces overseas. (Source: Population Estimates, Series P-25, No. 381, December 18, 1967, Bureau of the Census.)



Changing proportion of "natural" and "man-made" aspects of the environment. As a result of population growth and of using our increased technological and organizational power, more and more of man's environment is becoming man-affected or man-made, except where special provision has been made to keep the influence of man and his machines at a minimum (for example, in wilderness areas and natural areas created to provide a base line for ecological studies).

The primary threats to man's physical and psychic survival, to his health and well-being, now increasingly stem from his own creations, from the environments which he has created or altered, from the natural forces which he has harnessed, and from the institutions, techniques, and tools which he has invented in order to remove the constraints of space, time, and low capacity to manipulate the environment.

Man no longer has the margin for error which space, time, and his relative lack of power once provided for his ecological mistakes.

He must, therefore, take care, in his relation to the environment and in his actions to shape it, that he does not make himself and his society more vulnerable to sabotage, disruption, and disaster—for example, if a small element of the system which he designs does not perform perfectly, if his shaping of the environment should have adverse effects, or if disturbances in the environment, such as floods, earthquakes, and hurricanes, should affect the areas in which he has settled.

We have had some sharp, recent experience with systems which created potentially disastrous effects when a small part of the system failed—for instance, the Northeast power failure and the Torrey Canyon tanker disaster.

In attempting to use our power to influence the environment, we should design for a range of contingencies—for the optimist when all works well and for the pessimist when much goes wrong. The test of our technical creations is not how well they perform when all parts work as designed, but how well the system runs and how widespread the damage is when a part of the system fails.

Since the environment influences man himself, and since man has increased power to influence his environment, man is, in many ways, through intent as well as inadvertence, and perhaps in ways he does not understand, increasingly influencing his own genetic, physical, and psychological nature—and that of his children—through the environments which he creates.

Because man's increased power to manipulate the environment has created a total environment which is increasingly man-made and in which man's margin for error is reduced, his only protection now is knowledge and wisdom in using his technological and organizational power. Man's ability to create adverse effects may be greater than his ability to perceive, judge, prevent, and control them. As a result of his inability to control wisely the purposes to which he puts his power, man may find that he is creating effects in his "natural" and "man-made" environments, as well as in himself, which he cannot control and which are adverse and irreversible.

Range of Alternative Future Environments

In attempting to look at the "natural" as well as the "man-made" aspects of man's future environment, one can project a number of possible alternatives, ranging from optimistic to pessimistic.

The many elements which will make up man's future environment vary with respect to: (1) probability of occurrence; from impossible to inevitable or zero to 100 percent; (2) popularity, or the extent to which the event is desired by the public or by specific groups, today or in the future; and (3) desirability.

The actual future environment which man will inhabit depends upon the nature and unfolding of the various trends which are helping to shape the environment and upon man's actions to influence these trends.

The crucial problem in looking at the future is to decide what is desirable among the range of possible future events and then to work for it, taking into consideration the probability that the future event will occur, the difficulty and costs of bringing it about, and the consequences of not doing so.

Within the range of possible future social and ecological environments, many pessimistic possibilities could be realized in the absence of adequate policies to prevent their occurrence.

For example, problems of external defense, international order, and war could become worse, with general nuclear war one pessimistic possibility for rapidly decimating our population, and, at the same time severely damaging our natural environment and our cities.

Large-scale loss of life due to ecological and technological disasters is not impossible, particularly if large and densely concentrated populations depend upon an ecology and large-scale systems of technology and organization which are highly vulnerable to disruption, breakdown, and misuse.

In the absence of adequate policies to protect against such natural hazards as storms, earthquakes, and floods, larger numbers of people could become vulnerable to disaster.

Other possible adverse effects of misusing our technological power have been mentioned, for example, global ecological imbalances and more intense and widespread disasters caused by:

1. Environmental pollution which upsets the chemical-thermal balance of the earth's atmosphere because of increased burning of fossil fuels, pollution of the upper atmosphere, and impairment of the cycle by which the carbon-oxygen balance in the atmosphere is maintained, through photosynthesis, by plants on land and in the ocean
2. Soil depletion and increased salinity of the soil
3. Poorly planned, large-scale, environmental engineering projects which trigger world-wide ecological effects—rapid or slow—which are adverse to man and irreversible

Increasing pressures to mass produce and construct, in a short time, large numbers of new buildings and housing units could cause a decline in diversity, quality, and choice in our cities. Without proper protection, the quality of the countryside, also, could continue to deteriorate because of junkyards, billboards, power lines, overenriched lakes ruined by algae growth fed by wastes from cities and farms, polluted streams, and erosion of hillsides and of the many new inadequately protected construction sites.

The cumulative and mutually reinforcing effects of many environmental changes on the ecology and on man's physical and psychic health are potentially dangerous but not well known.

For example, we do not know enough about the long-term ecological, somatic, and genetic effects of various chemicals used in fertilizers, pesticides, and herbicides; of such environmental contaminants as radioactive wastes and lead; of the concentration of various poisons through the food chain, or of their cumulative and interactive effects. Nevertheless, the outpouring of toxic materials into the environment is already great and increasing.

Even though the nation's economy, our gross national product, and our per capita income will continue to grow, individual standards of living could decline because of inadequate policies and programs to protect the environment. Since the social, physical, and biological aspects of man's environment interact, deterioration of the non-human environment could help to create economic and social decline.

Moreover, failure on the social and political level could, in turn, contribute to deterioration of our physical and biological surroundings. For example, the educational system could fail to transmit to succeeding generations the cultural values which underlie the nation's political system as well as the attitudes and skills essential to maintaining environmental quality.

Internal order as well as ecological balance and environmental quality could break down or become more difficult to maintain. Or, their maintenance could be based more and more on "external controls" and repressive measures, on the threat of punishment and constriction of freedom.

Man's actions to avert the various environmental threats which now confront him will help to determine whether or not his future environment will be one in which he can thrive as well as exist.

Depending on his actions to prevent the occurrence of future pessimistic possibilities, and to realize optimistic ones, man could enjoy more widespread and heightened values of, for example: natural beauty, clean air, water, and unlittered land; cities which are beautiful, exciting, and a joy to live in; rising levels of living; tranquillity and silence; privacy as well as sociability; diversity, individuality, and choice; justice and security; political freedom, the opportunity to influence and participate in the decisions which affect his welfare and that of his children; democratic, representative government; and the opportunity to develop his personality to the maximum extent.

We must remember that the optimistic projections will not automatically come about without human effort. Nor will we prevent the pessimistic projections from coming true if we do not work at it. In fact, projections can become self-denying or self-fulfilling prophecies, depending upon their effect on human attitudes, effort, and will.

When people view any particular future alternative as necessarily inevitable, such an attitude tends to generate self-fulfilling or self-denying prophecies, depending on whether we see the inevitable as optimistic or pessimistic. For example, a pessimistic projection which is viewed as inevitable can become a self-confirming prophecy through reducing any effort to prevent its occurrence, thereby increasing the probability that it will come true. An optimistic projection which is viewed as inevitable can become a self-denying prophecy through reducing the effort devoted to bringing it about, thereby reducing the probability of its coming true.

On the other hand, if the future is regarded as open and subject, to some extent, to human manipulation, then this will tend to leave room for the creative exercise of human wisdom, will, and effort.

Control or Influence of Trends

Having outlined some of the important trends confronting the United States, and a range of alternative environmental outcomes associated with these trends, the question arises: Should we attempt to "adjust" to the trends, or to "influence" and "control" them, or both?

Assuming that "adjustment," by itself, is not an adequate guide if we wish to promote economic growth, individual well-being, and environmental quality, we then need to consider what can be done to "control"—or at least to "influence" the various trends which will affect man's future environment. What can be done to make more probable the optimistic rather than the pessimistic projections?

Technological and organizational power. It is crucial that we control the uses of our increasing technological and organizational power to affect our environment since to date, we have used this growing power in an unbalanced way:

- To limit deaths, but not, at the same time and in the same degree, to limit births. As a result, no matter how efficient the technology, skill, and organization devoted to producing, expanding, and making more efficient use of resources, population now outpaces production in many parts of the world, with tragic results.
- To use, destroy, and deplete resources for immediate benefit, without sufficient regard for the resource needs of future generations and without providing adequate knowledge and skills to compensate for the depletion.
- To pollute our land, air, and water, but not to prevent pollution, clean it up where it occurs, and restore the damaged environment.
- To promote economic and population growth, but not to protect and promote environmental quality.
- To create and apply new knowledge and powerful technologies without, at the same time, acting to prevent and limit the damaging side effects of using this knowledge and technology.

There is a need now to restore the balance in our use of science and technology—in our attitudes, laws, and institutions. For science and engineering, by themselves, cannot save us from our lack of wisdom and vision in using science and in managing our technological power.

Additional technological power and efficiency, applied in the same manner that we have applied them in the past to our environment and to the forces of nature, will not necessarily save us from our lack of balance and wisdom in using that power.

We need, therefore, to perceive, predict, evaluate, influence, and control the effects of using our technological and organizational power so that the optimistic rather than the pessimistic possibilities will come to pass.

To carry out the research, planning, and operational programs to perform these activities, we need to create the necessary laws and institutions, in government, at the federal, state, and local levels, as well as in the private sector, in universities and industry.

We need to use our technological power in such a way as to affect the trends which, if unchecked, would realize the pessimistic possibilities. In other words, we need to influence population growth and distribution, the supply of and demand for resources and services, and the output of wastes.

Population growth and distribution. Problems of population increase as well as density could seriously jeopardize the ability of this and other nations to meet, concomitantly, their national goals for security, economic growth, welfare and well-being, resources, conservation, and environmental quality.

There is, therefore, a need to develop a population policy based on analysis to determine:

1. What, if various alternative projections for future population growth and distribution were to come true, the effects would be on the success and costs of our policies:

A. *To supply and conserve resources* (land, water, air, food, minerals, energy, timber, wildlife, wilderness, outdoor recreation and park areas, open spaces, natural beauty, silence, etc.)

B. *To provide services* (transportation, health, welfare, housing, sanitation, education, etc.); and

C. At the same time, *to protect and promote environmental quality;* that is, to prevent further pollution of our land, air, and water, to clean up what pollution remains, to restore the damaged environment, to rebuild our deteriorated cities and to create new ones;

D. To solve these problems within the existing framework of government and political and personal values (to protect and strengthen freedom of choice and representative, popular government and to limit the extent of intrusion of government into the personal lives of citizens).

2. Which, if any, of the various alternative projections for future population growth and distribution we should regard as goals for population policy, and the costs and benefits of achieving each; and
3. How, by what methods, we could achieve each goal. Programs for action to influence population growth rates and distribution could be based on such analyses.

Alternative goals for population growth might include, for example: (1) to insure that all American families will have access to information and services that will enable them to plan the number and spacing of their children, and thereby, to insure that any future American child will be a "wanted child"; (2) to achieve population growth in the United States which would increase more rapidly or more slowly than is projected; and (3) to stabilize United States (and world) population at less than its present size, or double its present size, or greater by a factor of 2.5, 3, or 4. Here, the question arises: At what level and when should this stabilization occur—in 40, 60, 75, 100, or 200 years?

Supply and use of resources and services. To help satisfy the increasing demands for resources, there is a need to increase the available supply, through research and exploration programs, and to make more efficient use of the existing supply through improved conservation, management, and pricing.

Moreover, if our aim is to increase individual well-being and standards of living, access to resources and services, as well as to promote overall economic growth, then the question arises whether we should attempt to limit the rate at which demand grows as well as to "satisfy" increasing demands for resources and services. This would require us to limit the rate at which population grows and puts pressure on our not unlimited ability to provide resources and services.

Control of waste output. If we are to protect the environment adequately, we must bring under control and manage the wastes of our society which threaten to poison and bury us and to destroy the ecological systems upon which we depend. We must, therefore, prevent, limit, manage, and control waste and pollution at each step in the process by which our economy and industry transform energy and materials, from raw materials through to finished products, to ultimate use and disposal.

This requires us to create more efficient and less wasteful industrial and economic processes, and to provide for use, reuse, recovery, and recyling of the waste products—solid, liquid, and gaseous—which are generated at each stage in our economic system.

Personal and Political Values and Control of Trends

To control and influence the trends outlined above requires "management" and control of people and institutions as well as of the environment. What is the relation between: (1) "management" of the environment and of the "trends" which will affect the environment, and (2) personal and political values?

"Environmental management" involves the monitoring and manipulation of physical, chemical, and non-human biological systems—the oceans, river basins, watersheds, airsheds, industrial, agricultural, and municipal wastes, and populations of various species of fish, birds, animals, insects, and plants.

But such objects are only part of the environmental quality problem. Human persons, their attitudes, ideologies, practices, social systems, and institutions are also part of the problem of maintaining environmental quality. They must also be part of the cure.

If more "efficient environmental management" involves human persons, attitudes, and institutions, then what are the implications of "efficient environmental management" for such values as freedom, privacy, autonomy of personality, dispersal of power and pluralism (particularly under conditions of rapidly increasing population), industrialization, urbanization, and use of technological power to manipulate the environment?

How can the United States promote environmental quality, and, at the same time, protect and promote various important personal and political values under conditions in which an additional 100 million people are projected to be added to the United States population in a short 30 years?

If the United States is to control the effects of its citizens' actions on the environment, and at the same time, to protect their personal and political values, there will be a need to rely, to a large extent, on internal psychological controls—rather than on the external threat of law or punishment. And, if such internal controls are to be used with a rapidly expanding population, then great reliance must be placed on education for conservation and environmental quality—at each stage of a person's life—in the home, through school, and in other areas of activity.

The need to promote and to reconcile "environmental quality" and "environmental management" with such values as freedom, privacy, and autonomy of personality, dispersal of power, and pluralism is one which places a critical responsibility on the educational system in general, and on the teachers of science in particular.

Conclusion

Our current environmental crisis is due to man's misuse of power—to one-sided use of his capacity to control the forces of nature and to his lack of understanding of himself and his lack of wisdom in using his power.

Much remains to be done for environmental quality—in many areas—in terms of attitudes and education, laws and institutions, research, planning, and operational programs.

Science teachers who convey the attitudes and skills needed to protect and promote environmental quality are on the forefront of man's effort to restore balance and harmony—within himself, within nature, and between himself and nature.

We must restore wisdom and balance in our actions, in the use of our power, and in nature. Time is short. Much of our damage to the environment is irreversible; what we destroy cannot be restored and is lost forever.

The accelerating damage which we do to nature and to ourselves will not wait for us to catch up, nor will it wait while we refine our understanding of this damage.

We must learn, and science teachers must help future generations to learn, to restore the balance:

- Between our power and our wisdom in using that power
- Between our power to create and our power to destroy and disrupt
- Between our efforts to prevent injury and our efforts to heal the damaged environment
- Between our efforts to understand environmental problems and our actions to prevent and correct these problems

Our power has exceeded our wisdom.

Our power to destroy the environment has surpassed our power to correct the damage, to conserve and create.

Our efforts to prevent have lagged behind our efforts to cure.

Our cures have been too little and too late.

And, we have often allowed the quest for more perfect knowledge to deflect us from acting now with what knowledge we have. □

ON THE NATURALIST NATURE OF MAN

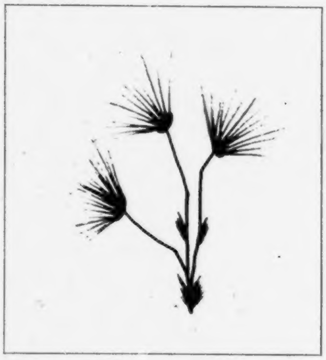
Richard R. Graber

EXCEPT in the love that one human has for another, there is perhaps no greater delight in life than the pursuit of knowledge about nature. To feel reverence for the earth and the life it supports, to sense the endless complexity and variety, the innate beauty of this fantastic laboratory, is or should be, part and parcel of the gift of life. A child's curiosity, born of ignorance freely admitted, is much of that gift, and to see this trait die with the sophistication of young adulthood, is something of a tragedy not only for the individual but for the world. It is a tragedy for the individual because it squeezes his view of life into a narrow corridor so dominated by man that the real world is all but lost from sight. It is a tragedy for the world because the earth and all it contains require understanding.

By what circumstances a strong curiosity about nature is sustained in some individuals is not known, but this, whatever the cause, is the naturalist's magnificent blessing. He wants to understand the earth; he keeps asking questions and looking for answers.

From the time that life began on earth, it took perhaps three billion years or more, to produce an animal that was capable of understanding the world and how it works; capable of knowing all the parts, living as well as nonliving; and capable of understanding how the parts worked together, how they were related to one another. The problem of understanding this immense machine was beyond the comprehension of any human mind, or any generation of human minds. Not only were the earth's inhabitants seemingly infinite in variety, but each year the machine differed subtly from what it was the year before. To understand all this was a problem, or actually billions of problems, to tantalize and delight the minds of men for *all* the generations that would ever be. The metabolic processes that sustain us are common to all living things, but understanding has become the unique human function. Yet, understanding is not merely an end to itself, a kind of climax to a game that satisfies the intellect. It is probably the essential key to human survival.

In a more primitive world, where natural resources seemed inexhaustible, there was neither the pressing need for understanding nor the time to acquire it. Later, the technology which accelerated our dominion of the world and gave us time to search for knowledge, also greatly accelerated our need for it. Now, after a few thousand years of study, far from understanding the earth, we haven't yet found all its living parts. Each year hundreds of new species of insects are found, and even among the birds—probably the best known group—new species continue to be discovered. But discovering the species, however difficult, is only the relatively easy beginning. Trying to understand the impact of that species upon the world is the infinitely greater problem. We cannot fully understand the species until we know its relationship with every other living and nonliving part of the earth and their relationship, in turn, with all the rest. The threads which tie all living things together extend beyond the horizons in all directions around the world and back in time to the first metabolic molecule that passed its secrets on to another generation. Man, like it or not, is part of the system; he cannot act alone, for when he pushes the earth,



Dr. Graber is a wildlife specialist in the Section of Wildlife Research of the Illinois Natural History Survey, Urbana.

the earth pushes back. So complex and intricate is the system that we should not choose to lose one part of it for fear of losing ourselves. If, by some tragic circumstance, the millions of migrant birds which pass through every country should not appear some spring, would the land be just the same? Does this great energy pass without effect, or in some subtle but important and irreversible way would human survival be influenced? No one knows the answers, and we are probably a thousand years from knowing. Yet, seemingly oblivious to our own colossal ignorance, we rend the land for almost any economic expediency. The earth may pay us back in kind, and that might be some sort of justice, but is it justice for all those who would never know the incomparable privilege of life?

IT IS natural for us to dwell on day-to-day problems, to think of survival from year to year, if at all; to be concerned only with the here and now. But a very important part of the gift of intellect is the ability to learn from the past and to look to the future. For the naturalist there is a certain sadness in looking back, because naturalists cherish *all* forms of life, and the inevitable lesson from the past is that *no* species endures. It seems to say that, as in some primeval marsh there was a last lone *Brontosaurus* and is today a small relict band of whooping cranes, there will someday be that last lonely human, his species gone forever. Like everything else on earth, we as a population are continually changing, and it is comforting perhaps to think that there may be another human species when we are gone. But evolution requires time, and there is no one to say how much time we have. Countless generations of thoughtless creatures, now long since passed away, gave us the chance to be—to *think*. To that extent they are part of us, and what we have and what we are, we owe in some degree to the lowliest form of life. But what we owe we cannot pay the past. Nature makes no moral judgments. If wild creatures were ignorant, they were also innocent, with little power to change the world very fast. Unable to understand the effects of their existence, they had no responsibility to the earth or to its future; no obligation to its past. The power that came with intellect carried with it also obligation and moral choice. The ultimate morality is what Albert Schweitzer called a reverence for life, not merely for human life here and now, but for all life for as long as it may be. Whether ultimately for pride or tragedy, man seems to have the responsibility that goes with reason and the obligations which attend unrivaled power. Or is it, after all, that man, like all the rest, is merely victim of his circumstance, and even with the potential to understand, acts *without* understanding?

We are fond of the word "humanity." It calls to mind such terms as kindness, compassion, reason, and we seem to think these terms define us as a species, but is it so? A peregrine falcon that strikes a plover from its flock seems devoid of compassion, yet its ministrations to its mate and to its young appear most tender. The peregrine kills for food and probably for no other reason. What the hawk thinks or feels is beyond our ken; we judge the bird by what we see it do and thus, to keep perspective, should we judge ourselves. A chef who drops a lobster in the boiling-pot may be as devoid of compassion as the falcon in a stoop, or the bombardier who drops his sticks of death on strangers. It is humanity, too, that kills itself *en masse*, that lets its populations run out of control in the face of mass starvation, that does not know itself. It is humanity that engages itself in racial strife, when genetic variability should be a source of pride and comfort as one of the strongest assets toward long-term survival. These things must be part of the definition, too, and they seem to belie both kindness *and* intelligence. Perhaps as we strive to understand the rest of the world, we will begin to understand ourselves. It is self-deception to exaggerate man's goodness, yet, in defining the species there may be a certain logic in stressing the kindly virtues, for it is in his compassionate conservation of other living things that man seems most truly set apart.

IF, INDEED, man does have intellect, and thus, its obligation, the manifestation of that obligation is the conservation of all forms of life. To extirpate a species is to destroy not only the present population but the promise of all that it could ever be. Could the circumstance have arisen, how might we have judged our own primitive forebears? But conservation is not simply blind altruism. We do not truly understand the role of a single species in the ecology of earth or man. Our judgments of other species are superficial at best and concern only immediate, proximate values. As free-living populations are continually changing, so are the relationships between populations, and what today we deem our natural enemy may a thousand years from now be our ally in a different struggle. The world's natural resources do not belong to us any more than they belonged to our forebears.

First and last, naturalists are conservationists. Life and all the things upon which life depends are the ultimate wealth, and the maximum production of life depends upon nothing more than *long-term* survival of the greatest number of species. This in turn, now seems to depend upon the knowledge and understanding of one species. The billions of living things of all species which could come after us on through the millenia can be sacrificed by these millions who are here now. Wouldn't this be the ultimate crime?—to use our intellect greedily to push the earth too far and cross that imperceptible line to mass extinction? It is even conceivable that we have *already* crossed it. So little do we understand the ecology of earth that almost certainly we will not know *when* we have crossed the line toward extinction. What a grotesque irony it would be if billions of years of organic evolution produced an intellect with the potential to understand, only to have it be the most destructive force of all. For life is wondrous whether we think of it as a biochemical accident or as the product of a creator.

Man's technological prowess, however magnificent, is no true measure of human intellect. A far more important measure is how well we understand the *total* effects of our actions, and how carefully we govern those actions. There is an old truism that species doomed to extinction are often marked by some kind of overspecialization. These species, in form and habit, fit neatly into some tenuous part of the environment—they are too successful—up to a point, and then their narrow approach to life pays them off with oblivion. The human mind too narrowly used in pursuit of untrammeled technological power may represent a form of overspecialization that is carrying man too far too fast. We must understand *where* it is carrying us, what we are doing to the world. If the net effect of man's existence is to accelerate the extinction of species, including himself, to what avail is technology? Perhaps the human species could go on another million years or more, but when we consider what has been done to this continent in just two hundred years, the long haul seems very long indeed. It is regrettable that we do not understand how our day-to-day living as individuals affects the long-term survival of our species, but it is far more regrettable that all too often we seem not even to care. Each individual represents the species and bears responsibility for its character. If, as individuals, we are thoughtless and insensitive, then the species is mindless, drifting senselessly.

As a species we are engaged in a vital race, and no human endeavor was ever so complex or so important. On the one hand, with our technological power, we are plundering the earth's resources at a continually increasing rate, and on the other, we are pursuing ecological understanding at an agonizingly slow pace. The critical question is this: Is there time to acquire sufficient understanding to keep from passing that point of no return from the void of oblivion? To understand enough to know both what we *should* do and what we dare *not* do is the monumental intellectual problem, awesome by itself, but beyond that is an equally important moral question: Will any people deny themselves wasteful programs which promise immediate gain for the benefit of those unseen strangers who will be our inheritors? To solve the intellectual problems without solving the moral problem is probably pointless, and the possibilities for failure on both issues seem very high from where we stand. In the last analysis only survival is meaningful. If we don't survive as biological entities, all else—political and economic considerations, everything—is academic. The problems of survival are ultimately biological problems, but to stress the need for ecological understanding is not to debase any field of inquiry. Though ecology is biology, it does not end there. Indeed, it is probably without end. Disciplines of study are no more isolated unto themselves than is man, or ant, or mollusk. Earth ecology extends into the universe beyond the reach of man and concerns the invisible structure of matter, as well as the social behavior of wasps. To place restrictions on the pursuit of knowledge is to make our view too narrow. Whether by design or accident, man has come to have a noble trust—the conservation of life and earth, through understanding. To that trust and to that understanding our energies as a species should be dedicated. So great are the problems that we could put all the human resources not required for food production and essential commerce to work on ecological investigation and education, and we still might lose the race.

It is interesting to contemplate what history will reveal. Was man an intelligent species after all? Or will the last humans decide that men never truly realized their potential, that intellect was sham, that over strife for petty causes, the one real cause was lost? It should be our hope that for a long time to come, men will ponder their potentiality, learning to measure success not so much by what they had, but what they left behind. □

Freedom and a Varied Environment

R. THOMAS TANNER

Assistant Professor
Department of Science Education
Oregon State University
Corvallis

CONSERVATION of natural resources is a venerable topic in the secondary-school science curriculum. The concept has never been more important than it is today, and yet it seems to have lost its vitality in the curriculum. It is the thesis of this article that the concept must be newly defined and set in a new intellectual context if its present import is to be clear to educators and students. This article is an attempt in this direction. Conservation will be defined as the maintenance of a maximally varied environment, and the relation of conservation to human freedom will be demonstrated.[1] I shall explore the denial of freedom which follows from an expanding economy based upon an expanding population. I shall conclude with implications for the teaching of science and with a summary of closely related issues and writings.

Since this is an essay, a statement of personal opinion, the reader will forgive occasional use of the first person singular; such usage is simply less clumsy in an essay than is the consistent avoidance of it.

Conservation has been taught in different ways. It has been taught as a set of rules, such as, "Farmers should plow around hillsides rather than up and down them." It has been taught as student activity, such as the planting of fir seedlings or the building of wood duck nests. It has been taught as an extension of conceptual schemes, such as the complementarity of organism and environment. It is proposed here that conservation be taught as an idea, an idea of vital importance to man as we hurtle toward the 21st century. First, the term needs a new and viable definition:

Conservation is the maintenance of a varied environment offering maximum freedom of choice to mankind and to its individual members, in perpetuity.

Individual freedom is the most basic tenet of American democracy. We have always held it worth fighting and dying for, and rightly so. Today, we find individual freedom increasingly threatened, not just from without, but as a result of our own technology and its societal concomitants. It was obviously no series of random events which saw *Brave New World, 1984, Walden Two,* and *Fahrenheit 451* written in this century of science.

The concept of freedom subsumes the idea that each man shall have freedom of choice: in diet, in dress, in faith, and *in habitat*. From this idea follows the desirability of a spectrum of habitats ranging from metropolitan complexes through isolated villages to wilderness. In such an environment, the urban and urbane have access to the cultural amenities of the city, but others are not denied the possibility of floating a wild river if they so desire. In such an environment, those preferring the atmosphere peculiar to small and isolated communities may find employment in such places and are not forced into urban migration. Generous samples of pastoral and agricultural habitats are available to those who wish to live near them. All species are preserved in their wild state along with the ecosystems necessary for this. As one chooses, he may place himself shoulder-to-shoulder on Broadway or alone on a desert mountaintop. "May place himself" are the key words; freedom of choice the ideal. Maintenance of such an environment is a proper concern of conservation today.

Probably few students would deny the desirability of a maximally varied environment, once they comprehend its inseparability from the idea of freedom. Even young people who have no desire ever to set foot beyond the suburbs will be slow to deny the right of others to do so, to be *able* to do so. This suggests that the pleas of conservationists and preservationists may often fall on deaf ears because of two major fallacies in their argument. Discussion of these fallacies will serve to illustrate, by contrast, the power of this new definition of conservation.

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[1] The writer is indebted to Jim Harleman for his insight into this relationship.

First, appeal is frequently made to the obvious desirability and inherent beauty of wild species, wild places, and pastoral-agricultural settings. But most of the populace are simply unresponsive to such appeal because they operate from different premises. For some, the desirability is not obvious, the beauty not inherent. For many others, the appeal is not foreign, but this concern is not very high on their personal list of priorities. The conservationist argument is thus akin to that of the religious zealot, profoundly convinced of his own faith but unable to proselyte an unlistening, listless public. To the zealot I can offer no advice; to the conservationist-teacher I suggest appeal to the principle of varied environment as the only possible physical setting for a free society. In this I am encouraged by the unrest of today's youth. Among their rallies for human rights, freedom of speech, peace, and love, there has been little mention of the conservation of a varied environment; however, their very concern for the aforementioned concepts argues for their potential as a generation of conservationists, even if it grows from a respect for mankind rather than from a love of nature. They need only understand the relation between a varied environment and the freedom of man. (Of course, these remarks should not be interpreted as a blindly liberal blanket endorsement of all youthful dissent, with its fair mix of carping, pseudo-issues, and even self-seeking.)

The second fallacious appeal of the conservationist-preservationist is his frequent opposition to dams, highways, and tracts, *per se* and *in toto*. In the face of the steady one-way homogenizing of the environment, one can certainly sympathize with this view. A more widely acceptable argument, however, might be that development decisions should be based upon the principle of varied environment. Permit illustration. In California, a hundred carbon-copy canyons cut through the chaparral of the coastal ranges to converge upon the Sacramento and San Joaquin valleys. In such a habitat, a few dammed canyons serve to increase the variety of the environment and thus extend the freedom of choice. Then, the water-ski crowd are not deprived of their rights any more than are the naturalists, nor should they be.

Of course, our students should come to appreciate the distinction between a few dammed canyons (which maximize choice) and a hundred dammed canyons (which eradicate choice). They should be able to distinguish also between the damming of a carbon-copy canyon and a unique one, such as Glen Canyon. It is proposed here that the soundest principle which they can use to judge the worth of new projects is the principle of an optimally varied environment. At the same time, they must realize that fundamental attitudes regarding population and progress also bear examination in light of this principle.

IT IS mandatory that students next comprehend the following hypothesis: *from this point in time onward, freedom of choice will vary inversely with population.* In former times this was not always true—large families and growing urban centers were needed to assure freedom from want. Today, technological advances have removed the necessity for continued population growth. Yet the population *does* grow and accumulate greater personal holdings of material wealth at the same time. Consequently, the distribution of types of habitat becomes increasingly and inevitably unbalanced. Megalopolises spread where farms existed. A wilderness area is legislated but becomes so overrun with visitors that it is wilderness only in name. (Sanitation has actually become a major problem in some federally-designated wilderness areas.) Certain habitats and their indigenous species are destroyed by pollution or development. The viewing and the logging of certain lumber species become mutually exclusive. Supplies of fresh water, minerals, and even oxygen become depleted. A low dam is built today in order to supply needed power while saving a few miles of wild river, but tomorrow's demands for power necessitate another dam, and the entire river is gone. An ever-larger portion of the populace finds itself unable to escape the suburbs except by driving most of the weekend. Thus population growth combined with material wealth brings a steady homogenizing of the environment, a reduction in the choices available, a limiting of human freedom.

Students must come to realize, then, that optimum freedom of choice will be possible only when we have a stabilized population. But to stabilize our numbers we will have to revamp an economic system which is dependent upon population expansion. Our students must see the fallacy in equating "growth" with "progress." They must understand that production of material goods must be a national means, not a national end. They might well examine the role of advertising in the creation of superficial needs, and the role of consumership in America today. They might study the problems of education and training appropriate for bringing about more worthwhile utilization of human time and energy. They should be brought to question whether the production of large numbers of more little consumers is really the ultimate patriotic duty. They must come to understand the distinction between freedom and power as exercised by both management and labor. They should discuss the morality of trade in leopard coats, crocodile handbags, and exotic pets, and of washing-machine advertisements which lionize large families. They must realize the inappropriateness of complacency. (Only 57 impoundable miles of the Columbia River in the U.S. remains undammed, and this stretch is scheduled for inundation soon. [3] There were an estimated 1,000 white rhinos in the Congo in 1960; the present population is estimated at 100 to 200. Poached trophies representing 700 were recently seized enroute to the Middle East. [1] Such illustrations of the urgency of the situation would easily fill a volume.)

What has all this to do with the science teacher? One answer, of course, is that the problems discussed herein are products of our science and technology. The population problem is a manifestation of medical advances, based in turn upon increased basic knowledge in biochemistry, genetics, and other sciences; the corollary homogenizing of the environment is accomplished by sophisticated means of energy utilization. Further connections will be obvious to the ecologically oriented biology teacher.

The science teacher may ask, "But if I find time for such matters in the science curriculum, when am I left time to teach *science?* Why not leave this to the social science teacher?"

Whether the ideas presented herein are more properly the domain of one discipline or another is a moot point. *Someone* must be responsible for conveying such ideas to the students. If an interdisciplinary effort among teachers of science, social science, literature, agriculture, and so forth, is implied—then so be it. If a completely new curriculum in the secondary schools and in the training of teachers is implied—so be it. If entirely new academic specialties for secondary teachers is implied—so be it. If the schools must reduce the study of "pure" and "genuine" science, in favor of increased discussion of important social issues affected by science and technology—so be that as well.

I HAVE tried to avoid being overly diffuse in this brief essay. Allow acknowledgment of some omissions: (1) The discussion has been largely national in character, with frequent reference to the American ideal of freedom. This does not preclude the extension of the argument to other nations; in fact, the argument assumes the necessity of a world order of free men. (2) I have addressed myself exclusively to the rights of men. That the rights of other beings deserve recognition is acknowledged enthusiastically by this writer; however, that thesis requires longer exposition than can be devoted to it here. (3) I am not so naïve as to assume that the creation of an enlightened citizenry is alone sufficient for necessary social change. Those who exercise power and wealth must be equally enlightened. They must be responsive to an intelligent populace. (4) Footnoting and reference to other writings have been minimal to this point. Yet the issues discussed herein should be placed in the perspective of writings dealing with inextricably related issues. Some prime examples, all of which contributed in some way to the formation of the present article, follow.

A lecture by Snow [13] was the classic elucidation of the chasm that has grown between scientific-technological advance and our outmoded institutions and modes of thought. Recent papers by Hurd [7] and Fox [4, 5] are addressed forcefully to the need for the science curriculum to concern itself anew with the humanistic ends of science and technology. Some of the best presentations of the problems of population growth are those by Ehrlich [2], Udall [15], and the Department of the Interior [8, 10, 11, 14] under Udall's secretaryship of that department. Ribicoff [12] proposes programs for revitalizing the economy of rural areas and isolated small cities. The novel by Gary [6] will be deeply moving to some students; it is an artistic and aesthetic expression consistent with the ideas discussed herein.

Some readers (like the writer) may enjoy classifying statements of educational philosophy under such taxons as realism, idealism, or experimentalism. The present essay is unabashedly representative of a Reconstructionist persuasion. (One should consult the writings of George S. Counts and Theodore Brameld for important enunciations of Reconstructionist philosophy.) I should like to utilize Van Cleve Morris' [9] description of Reconstructionism as a fitting conclusion for this paper:

> A desired future does not come about by making adjustments to changing conditions. A desired future comes about because men want it, plan how to achieve it, and execute their plans to reach it. And if men do not soon take a militant and activist stance concerning the kind of world they want, they will most certainly be blown to cinders.
>
> The school's job, then, is not merely to teach the young "how to manage change," but to teach them how to promote and incite change toward a specified social goal. No other institution in modern society, so the adherents of this position contend, is so aptly fitted for this new role. Organized religion, business and industry, even government itself, are all bogged in timid conservatism, still operating on last year's precedents and this year's clichés. Talk of "excellence," talk of "automated learning," talk of "science *and* the humanities." They all die on the tongue as essentially trivial in the face of global requirements for a massive change in educational outlook. The school's necessary role is one of social vanguard. Its clients are the young and their destiny is to take charge of the future. The school's job is that of reconstructing present-day civilization. Nothing short of this can seriously be considered truly educational.[2]

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James D. Sears

AN ENVIRONMENTAL AND ECOLOGICAL INVENTORY

NATURE is never static, nor is a totally natural environment always the most suitable for civilization. We must use and reuse our resources and shape our environment so as to leave a better quality of living to future generations—generations which must also face a challenge in their use of resources. This means that we need to be far better informed about our resources, and about our historical and cultural treasures, than we are at present.

What we do to, for, or with the environment must begin with a plan—a plan aimed not at determining whether a specific engineering solution is economically justified, but at finding the best solution to the problem and at meeting the varied needs and aspirations of the people. Planning seeks not to justify projects, but to identify and evaluate the consequences of alternative means for solving problems and satisfying needs. Planning seeks to illuminate the choices available for the people and their representatives who must make the final decision.

The author is chief of the Environmental Resources Branch, South Pacific Division, Corps of Engineers, San Francisco, California. The outline for a regional environmental and ecological inventory presented here was prepared for the 1970 Westinghouse School for Environmental Management. It was designed as a blueprint for study of an area under consideration for a power facility, to assure ecological and cultural compatibility of the installation with other aspects of the area. The comprehensive outline could well be used by environmentalists and by teachers and their classes in studies of the ecological and historical characteristics of regions.

Environmental planning imposes a number of new and broad requirements upon the planning process and the planner. In general terms these are:

1. The environment must be considered from an ecological or systems point of view. It must be recognized as an infinitely complex system of interrelating and inseparable elements and relationships—a system in which any impact upon one element or relationship has consequences of varying degrees throughout the whole.
2. The full range of likely consequences of proposed environmental manipulations, both upon the environment and upon man, must be defined more clearly and assessed with greater sensitivity.
3. New kinds of environmental information must be systematically collected and evaluated.
4. The planner must insert himself to a greater degree in the public arena and be prepared to face problems and issues of ever-growing scope, involving conflicting objectives and values. He must obtain not only the physical and ecological information necessary for good planning, but also a knowledge of the public's desires, needs, and frustrations.
5. The environmental planning effort must be multidisciplinary, including the natural and social sciences.

Environmental questions are, for the most part, extremely complex, involving combinations of social, psychological, economic, ecological, and a variety of other problems and issues. While there has been some research in the past on various specialized aspects of environmental problems, very little research has been interdisciplinary in nature or oriented toward applied problems, although some of the larger universities have initiated a few such projects. This deficiency stems largely from the fact that most existing research institutions and researchers are not problem oriented but, rather, are specialized along traditional disciplinary lines. As a result, there is a decided dearth of information and analytical and evaluative methodology with which to understand, assess, and deal with environmental problems. Thus, it is impossible in many cases to predict accurately the effects of a given action or to define the values which the public places upon these effects.

The obvious need is to improve the overall state of environmental arts and sciences and the institutions responsible for their development, particularly in terms of making them more responsive to interdisciplinary problems. Over the long run, this will require a relatively massive joint effort by the scientific and academic communities, with the support of the private and governmental sectors. Existing and evolving basic knowledge must be synthesized, integrated, and reworked into usable, applied information, criteria, and working tools which can be applied by the planner.

THE environmental inventory should be a broad *regional* inventory, accompanied by a *project-related study* if the inventory is undertaken for the purpose of siting or planning an installation—commercial, industrial, recreational, or other—that might affect the environment. The broad regional inventory may be envisioned as an environmental data bank, obtained largely from a review of pertinent literature and existing reports by others. The project inventory will contain detailed information obtained through field trips and contacts with local residents.

The regional inventory will, for example, identify the broad boundaries of a delicate or scarce ecosystem, historical or archaeological areas, public recreation areas, stretches of wild or scenic streams, and unusual ecological conditions, including plant or animal communities far removed from normal ranges.

The environmental features which should be inventoried in both a regional and a project-related inventory are classified under four headings:

1. Historical and archaeological
2. Visual
3. Ecological
4. Land use (cultural)

Regional Environmental Inventory

This inventory deals with unique or outstanding occurrences which are significant to the state or nation, which may not necessarily be designated formally.

ARCHAEOLOGY-HISTORY

- I. Archaeology
  - A. Designated archaeological areas or sites (Indian mounds, caves, petroglyph)
  - B. Potential archaeological areas (Conditions of terrain, climate, and cover similar to known sites)
  - C. Tribal or cultural boundaries
- II. History
  - A. National-state designated sites
    - 1. Pre-Revolutionary War
    - 2. Pre-Civil War
    - 3. Post-Civil War
  - B. Known historic land and water trails
  - C. Important but undesignated sites

VISUAL

- I. Natural
  - A. Overlooks, vistas, panoramas
  - B. Unusual land forms
  - C. Woodlands, marshes, meadows, agricultural areas, etc., with exceptional visual qualities
  - D. Outstanding water resources
  - E. Unusual plant or animal communities
- II. Man-made
  - A. Communities with architectural integrity
  - B. Outstanding architectural examples
  - C. Transportation systems
  - D. Mineral extraction
  - E. Land use (unusually aesthetic results of agriculture, forestry, or commercial endeavors)
  - F. Recreational (exceptional visual impact of natural and commercial areas and developments)

ECOLOGICAL

- I. Land Physiography
  - A. Estuarine
  - B. Coastal plain
  - C. Piedmont
  - D. Foothills
  - E. Inland plain or valley
  - F. Mountains
- II. Life Zones
  - A. Plants
  - B. Animals
- III. Important Ranges of Aquatic Life
  - A. Marine
  - B. Brackish
  - C. Fresh
  - D. Anadromous
- IV. Important Ranges of Wildlife
  - A. Concentrations
    - 1. Breeding
    - 2. Feeding
    - 3. Resting
  - B. Migration routes
  - C. Winter/summer ranges
  - D. Rare and endangered species
- V. Special Areas
  - A. Wild and scenic rivers
  - B. Parks
  - C. Conservancy districts
  - D. Refuges

LAND USE (CULTURAL)

Areas that are unique or outstanding or of extreme economic significance within the region, state, or nation are those used for:

- I. Mineral Extraction (gold, coal gas, oil)
- II. Cropland (agriculture, forest)
- III. Water Bodies (reservoirs, canals, rivers, streams)
- IV. Developed Areas
  - A. Industrial
  - B. Commercial
  - C. Institutional
  - D. Residential
    - 1. Urban
    - 2. Suburban
- V. Reservations (public or private)
  - A. Parks and recreation land
  - B. Wilderness
  - C. Historic or archaeologic
  - D. Wildlife refuges
- VI. Barren Land
- VII. Population Distribution

Project-Related Environmental Inventory

The purpose of this inventory is to provide the planner or decision maker with basic information as to the environmental quality of the project area during plan formulation. It will indicate those environmental features that are unusual, valuable, or rare, as well as those especially important to the local residents. We are concerned about those features of high quality and with unusual characteristics. We are also concerned about those areas, sites, or conditions that have become degraded and that offer an opportunity through advance planning to be reclaimed, improved, or beneficially altered.

The information for this inventory can be obtained through field investigation, including visual observation and contacts with local public representatives, private organizations, and individuals. In addition, the newspaper files and county records should be utilized.

Specific environmental features should be discussed with the following types of groups or individuals:

- A. Special interest groups
  - 1. League of Women Voters
  - 2. Sierra Club
  - 3. Audubon Society
  - 4. Izaak Walton League
  - 5. Service clubs
- B. Elected and appointed officials
  - 1. County supervisors
  - 2. Mayors
  - 3. Councilmen
- C. County agents
- D. Historical societies
- E. News media
  - 1. Editors
  - 2. Feature writers
- F. Fish and game field representatives
  - 1. Federal
  - 2. State
- G. Academic departments
  - 1. Biology
  - 2. Landscape architecture
  - 3. Urban planning
  - 4. Sociology
  - 5. Architecture
- H. Interested Citizens (obtain names from news clips or in discussion with others)

Project Area Environmental Inventory

This inventory deals with unique or outstanding occurrences which are significant not only to state and nation but also to the county and community.

ARCHAEOLOGY-HISTORY

- I. Archaeology
  - A. Designated by National Park Service or state agency

  B. Known archaeological sites—but not designated
    1. Excavated
    2. Unexplored
  C. Petroglyph, cave, cliffs, etc., with legendary history
II. History
  A. Designated site of national or state significance
    1. Pre-Revolutionary War
    2. Pre-Civil War
    3. Post-Civil War
  B. Site of first building in community
  C. Oldest standing building or buildings
  D. Known historical land and water trails
    1. Fur trappers
    2. Immigration routes
    3. Commercial

VISUAL

I. Natural
  A. Overlooks, vistas, panoramas
  B. Unusual land forms
    1. Cliffs, palisades, gorges
    2. Balanced rocks, castle rocks
    3. Exceptional glacial remains
    4. Caves
    5. Natural bridges
    6. Mineral outcroppings
  C. Outstanding water resources
    1. Lakes, ponds
    2. Rivers, streams, white water
    3. Waterfalls, springs, geysers, artesian flows
    4. Beaches, islands
  D. Visually unusual plant and animal communities
    1. Rookeries
    2. Virgin stands of timber
    3. Natural prairies
    4. Specimen trees
II. Man-made
  A. Architecture
    1. Individual buildings
      a. Church
      b. House
      c. Tavern
    2. Groups of buildings
      a. Villages
      b. Waterfront blocks
      c. Farm sets
    3. Bridges
      a. High trestle
      b. Suspension
      c. Covered
  B. Scenic roadways
  C. Historic Routes
    1. Canals
    2. Covered-wagon trails
    3. Indian
  D. Dams and reservoirs
  E. Lighthouses
  F. Mineral extraction
    1. Quarries
    2. Mines (strip and shaft)
  G. Land-use areas
    1. Agriculture
      a. Orchards
      b. Vineyards
      c. Others
    2. Timber management areas
  H. Recreation
    1. City parks
    2. Amusement parks
    3. Trails
    4. Ski slopes

ECOLOGICAL

I. Land Physiography
  A. Marine
  B. Estuarine
  C. Coastal plain
  D. Piedmont
  E. Foothills
  F. Inland plain or valley
  G. Mountains
II. Life Zones
  A. Dominant species
    1. Aquatic (floating and bottom)
      a. Plant
      b. Animal
    2. Terrestrial
      a. Plant
      b. Animal
  B. Subdominant
    1. Aquatic
    2. Terrestrial
III. Seasonal occurrences
  A. Aquatic
    1. Anadromous fish migration
    2. Spawning activities—finned and shell
    3. Feeding—high seasonal productivity
  B. Wildlife
    1. Feeding
    2. Breeding
    3. Resting
    4. Migratory routes
IV. Rare and Endangered Species
V. Special Ecological Areas
  A. Refuges
    1. Dedicated
    2. Undeveloped land
  B. Parks
  C. Wild and scenic rivers
  D. Conservancy districts
VI. Areas of High Food Productivity

LAND USE (CULTURAL)

Areas that are unique, outstanding, or of extreme economic significance to community, county, or state are those used for

I. Mineral Extraction
  A. Gravel
  B. Marble
  C. Gold
  D. Coal
  E. Salt
II. Agriculture
  A. Timber
  B. Grazing
  C. Orchards
  D. Vineyards
III. Water Bodies
  A. Reservoirs
  B. Harbor channels
  C. Locks and dams
  D. Canals
  E. Rivers
IV. Developed Areas
  A. Industrial
  B. Commercial
  C. Institutional
  D. Residential
    1. Urban
    2. Suburban
V. Existing Zoning in Project Area
  A. Indication of direction of development
  B. Initial indication of community feeling
VI. Reservations (public or private)
  A. Parks and recreation land
  B. Refuges
  C. Historic or archaeologic
  D. Natural areas
VII. Barren Land
VIII. Population Distribution

THE placement of all environmental features on a map or maps will provide a visual resumé of the features and their relationships to each other. It will provide a basis for discussion, in detail, of the manner in which the features were considered, enhanced, retained, or mitigated in plan formulation. Of particular importance is a determination of the particular feature's status in the range of scarcity. In addition to a map showing particular features considered desirable or scarce, the project environmental inventory will contain a description of "indicator" plants and animals, with some indication of the ecological factors which have resulted in their existence, as well as their status in the range of scarcity.

Such inventories will present data for an evaluation of the features as to scarcity; national, regional, or local importance; and the potential or necessity of improving, protecting, or mitigating the environmental features affected. In addition to raising "red flags" about features which should be preserved or left undisturbed, the inventory can also raise some "green flags" about areas that should be improved or enhanced. ☐

THE OTHER SIDE OF THE COIN

R. M. Billings

SIR Isaac Newton said it briefly, "To every action there is an equal and opposite reaction." He called it a law of motion. Emerson said it lengthily in application to people. He called it "The Law of Compensation." I intend to talk about the same principle, neither as briefly nor as lengthily. And certainly not as profoundly, for I call it simply, "The Other Side of the Coin."

The statement that a coin must always have two sides is hardly an earthshaking one. Yet this, one of the most straightforward and simple of facts, seems somehow to be completely overlooked in most of the discussions we hear today concerning pollution abatement and our environment.

One of your professors said to me the other day, "Teachers of science dare not make unidimensional attacks on multidimensional problems," and I could not agree more. Because of the respect in which your opinions are held, because the statement of scientific fact is a statement of truth (and we are all seeking truth), and because the scientific approach is the unemotional consideration of all pertinent facts, it follows that it is the responsibility of teachers to make sure that every student of science examines both sides of the coin.

Mr. Billings is the director of environmental control, Kimberly-Clark Corporation, Neenah, Wisconsin. This article is adapted from his address to the NSTA North Central Regional Conference in Milwaukee, Wisconsin, on October 1, 1971.

How do you go about getting people to think? Your pronouncements must not be in error—even in part—because if you make statements that can be disproved, you lose your credibility as a scientist. Neither can you build a straw man and pummel him as a politician can, or take the approach of an author who writes a book which depends upon sensationalism for sales. Sometimes you don't even dare to tell a student what is on the other side of a coin that he is viewing if you yourself haven't just checked it, because in recent years, it may have changed. About all you can do is to make certain that the student understands the need for turning each coin over and that he realizes that the coin always has the same value regardless of which side is up.

I would like to discuss a few "coins" here. As an engineer, I intend to state facts and let you draw your own conclusions. I know that I will be unable to resist offering my opinion from time to time, but when I do, I will try to point out that it is an opinion only.

LET US look at one of the "Reprocessing Coins" which today are being held up for all of us to see. Almost everyone has viewed "heads" and has expressed his approval emphatically and vociferously, but very few have bothered to look at "tails."

Let us turn the paper-reprocessing coin over, then, to see just what is on the other side.

First: We see that "paper" is a very general term like "animal" and that there are many types, classes, and grades of paper. To say that paper should be and can be recycled is as indefinite a statement as to say that a woods camp is being overrun by animals and that something must be done about it, without specifying whether the animals are mice or monkeys.

Second: It is not generally realized that paper can be reused in its own grade and class or downgraded to a less critical one, but it cannot be used to produce a higher grade or class. While we can make newsprint and magazine paper from recycled business papers and tissue, we can't make tissues and high-grade bonds out of magazines and newspapers.

Third: The production of deinked pulp from recycled or reclaimed paper creates a truly enormous pollution-abatement problem. The suspended solids per ton of pulp produced, which emerge as waste in the deinking process, represent a very high ratio of waste to product. It is standard to assume that for every 100 pounds of waste paper entering a deinking plant, only 75 pounds of deinked pulp will be produced. Twenty-five pounds of broken fibers, ink, and foreign materials must be disposed of in a manner that will have a minimum effect upon the environment. It should be noted also that this 25 pounds is no longer in a condition to be burned as was the raw waste from which it came, as it is now 80 percent or more water. To dry it out again will use up precious energy resources.

Likewise, from the standpoint of biochemical oxygen demand (BOD), a problem of major proportions exists. The amount of BOD resulting per ton of deinked pulp produced is approximately double the BOD derived from the production of a ton of kraft pulp. Typical values are 60 pounds BOD per ton kraft pulp vs. 110 pounds BOD per ton deinked pulp. I use kraft pulping for comparison, since kraft constitutes the major portion of all pulps produced in the United States.

The disposal of the sludge resulting from the 25 percent shrinkage and the increase in BOD resulting from the deinking process may thus open a Pandora's box of pollution-abatement problems. A paper mill which has operated for years on purchased pulp may be unable to install a deinking process because of lack of space for installing facilities to reduce the BOD, or for lack of disposal methods for the increased amounts of sludge produced.

On the other hand, deinked pulp is *not* required for the production of such things as paperboard, carton stock, roofing felt, or building board. Therefore, no such shrinkage is encountered, and the BODs resulting from the manufacture of such products are of a much lesser magnitude. Accordingly, many grades of wastepaper can be reused for these products. This is nothing new, however. Paperboard manufacturers have been doing this for years. In fact, their processes are built around recycling, and they couldn't stay in business without it.

A fourth point that becomes evident when the "other side" is carefully observed is that the use of paper over and over again by repulping, recycling, or reusing is a technical impossibility. Each time that fibers are used, parts break off, ends fray, and surfaces unwrap and gelatinize. Each pass, thus, changes the characteristics of the fiber and those portions broken off or gelatinized lose their paper-making properties. The good fiber remaining usually shows somewhat different qualities from those of virgin fiber. Some of them, like dimensional stability, are very definitely improved.

All reprocessing, however, results in loss of fibers. This is true even in the less-critical grades, and in the case of the higher grades of paper, as stated before, the loss may be 25 or 30 percent. This loss is irretrievable. Metals can be remelted. Sulfur can be precipitated from sulfur compounds. Calcium carbonate can be burned and slaked back to lime. By these physical and chemical processes, the usable and useful form of the substances can be reproduced over and over again. But cellulose fiber, which is paper's chief constituent, is not reproduced by some synthetic chemical or physical manipulation. It is the result of the growth process, which makes use of air, with its carbon dioxide, and water and sunlight. Only by this growth process is cellulose fiber recreated in such things as trees or sugar cane or flax or cotton. On the other hand, the decomposition of cellulose into its building blocks of carbon dioxide and water—rapidly by combustion, more slowly in the soil—is the ultimate recycling process for paper, a process which renders insignificant all others devised to date.

Still another point is that anything like 100 percent recycling of paper is and can be only talk. In addition to the factors already discussed, many paper articles are not available for recycling. Books and wallpaper, records and building materials are examples. A figure of 60 percent may be a realistic estimate of the maximum reuse attainable.

These considerations when we look at the "tails" side of the coin in no way change the "heads" side. Reprocessing is desirable in many cases and absolutely essential in others. Certain papers are given superior qualities by the addition of reprocessed pulp. We can and should do more reprocessing than we are doing now. Reprocessing of paper wastes will extend our forest resources.

TAKE another coin, such as the recovery of good fibers currently escaping from the paper mill in the waste stream. A view of "heads" shows us immediately that these fibers are of a quality that we could use in our products rather than lose in our wastes; that here is a resource that if recovered would reduce the total demand upon the natural resource from which it came; that recovery would be profitable; and that the technology exists for this recovery. This is a coin of high value and, accordingly, most of us have picked it up.

All of the facts listed above have been demonstrated, but we have found some interesting ones on the "other side." They are based on the fundamental fact that as you remove the good fibers from the waste, that portion remaining becomes more and more difficult to handle. Thickening of paper-mill wastes from which long fibers have been removed has proved to be a technical impossibility beyond a certain point. With a higher percent of water in the waste, difficulties in sludge disposal increase almost geometrically. Where land fill is employed, trucking costs are greater; and with incineration, the added cost of drying quickly offsets any gains in raw material savings. In addition, valuable energy sources are required to supply the heat needed to evaporate the water to the point at which the sludge will burn. We find that in certain cases, it may be desirable to let some of the good materials pass out in the waste so that the composite can be handled. Such an approach is necessary until technology gives us a better answer. Recovery, I repeat, is a coin of high value, but it is not of universal tender.

OR AGAIN, take the matter of separating paper from garbage at home—and I carefully add that while my point here is based on fact, it is primarily an opinion.

Here "heads" tells us that removal of paper from garbage at the source rather than at some later stage at a recycling plant is more efficient and gives a better quality paper product. We know also that the quantity of wastepaper normally a part of municipal garbage increases the processing load and cost, and, therefore, initial separation is a better answer.

I question, however, from viewing the coin as it appears to me, whether it is worthwhile to remove all of the wastepaper content in those cases where garbage is to be burned. Garbage must be dried before it can be incinerated. Wastepaper which came originally from trees, a renewable crop, can furnish heat in combustion, with a resultant saving of oil or gas or coal. None of the latter is a renewable item because the world is not producing these materials today. Perhaps in a million years another age of fossil-fuels production will occur, but this is a long, long cycle as compared with the 25 or 50 or 75 years needed for trees.

Note that in this last example, I said "as the coin appears to me." This is a tacit admission that I am really not too sure exactly what I do see, and this opens up an entirely different numismatic consideration. Is there a coin actually present and, if there is, what is its denomination? This certainly is a question of fundamental importance to every teacher of science.

THE EFFECT of colored tissue upon the environment is an excellent example of a coin that wasn't there. Some people just thought it was. They saw colored effluents below some paper mills; they had heard that the dyes used might not be biodegradable; and somewhere they had been given the idea that colors in tissue interfere with biological breakdown. Under better illumination, every one of the above speculations is revealed to be a mirage.

Because dyes have such a high affinity for fibers, what has been seen is colored fiber escaping, not dyes on the loose. Colored fibers pollute no more and no less than do white fibers. The answer is to minimize the loss of fiber of any type, colored or white, since the formation of fiber beds in our streams and waterways must be eliminated.

The fact that dyes may not be biodegradable in five days, the normal time test used, is immaterial. All of them will break down eventually; and even if the time were to be over a period of years, this would make no difference to the environment. After all, sand or clay or stone are not biodegradable. Also, biodegradability, which means by bacterial action, is only one way in which a compound may break down. Actions of the elements will probably be much swifter, as every housewife knows who has observed fading of dyed materials in sunlight.

The presence of dyes in tissue has never been shown to interfere with biological breakdown in the laboratory, in the sewage treatment plant, or in land disposal. Tests made by independent and by local and private laboratories reveal absolutely no effect. A literature search conducted in the Library of Congress at the direction of Senator Allan Cranston of California, failed to turn up a single piece of information to substantiate the theory that the presence of colors in tissues affects the environment in any way.

I COULD continue with examples of other types of coins.

Heads: The industries which are really making gains in pollution abatement and improvement of the environment. Tails: Those which are not.

Heads: Rivers and cities which are improving. Tails: Those which are declining.

Heads: My responsibility to my unborn grandchildren. Tails: My responsibility to my very much born son and daughter trying to exist in this economic climate so that my unborn grandchildren can get born.

And thus it goes, coin after coin; always a "heads," always a "tails."

True interest in ecology should serve as the common bond between all men of all nations, creeds, and colors, for man is an integral part of our ecological system. But simply being ecology-minded no more makes a man or woman an ecologist than being economy-minded makes him or her an economist. For the correct answers, we must go to those who know. If they don't know, at least these people are willing to admit it.

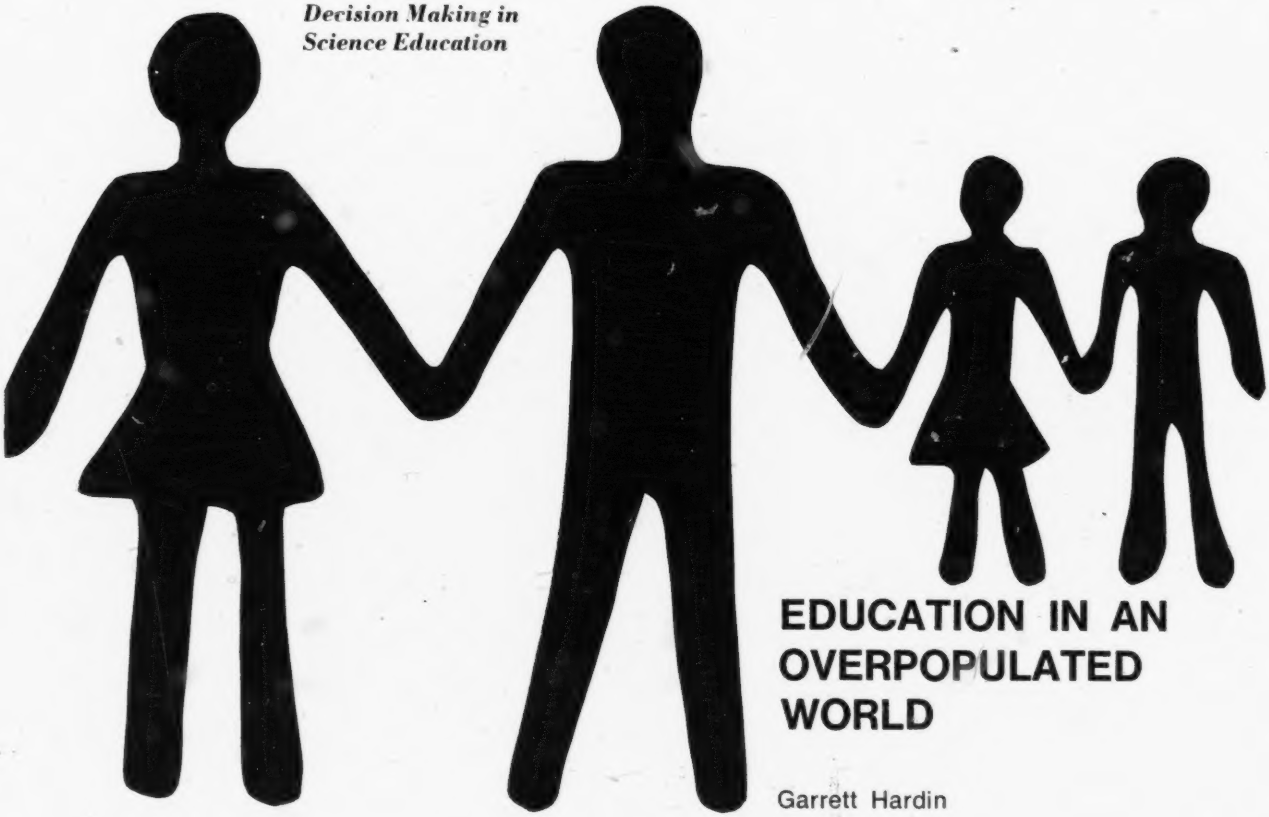
Which brings us full circle back to teachers and back to the problems that confront you in determining and disseminating ecological facts. Difficult as these problems are, they are not insurmountable if it is always borne in mind that man is a creature and, therefore, must be considered as a factor; if your opinions are given freely, but always labeled as opinions; if you continually counsel all to hold each coin up to the light of day and carefully to inspect each side in this light, you will have done your task. L. R. Treloar defines it thus: "The task of science is to explain the universe." Correctly, I might add. □

PART II

ASPECTS OF THE PROBLEM

Some relevant background material

Decision Making in Science Education



EDUCATION IN AN OVERPOPULATED WORLD

Garrett Hardin

HOWEVER much we may complain about the profession of education these days, we certainly cannot complain that it is dull! Teaching can still be *made* dull, of course; but censorious students will soon disturb the equanimity of any instructor who closes his mind to "relevance."

It was not always so. There was a time when most scholarly activity, including science, was a genuine refuge from the troubles of the world. This happy state of affairs was hauntingly described by Albert Einstein a long generation ago:

> Man tries to make for himself in the way that suits him best a simplified and intelligible picture of the world and thus to overcome the world of experience, for which he tries to some extent to substitute this cosmos of his. This is what the painter, the poet, the speculative philosopher and the natural scientist do, each in his own fashion. He makes this cosmos and its construction the pivot of his emotional life, in order to find in this way the peace and security which he cannot find in the narrow whirlpool of personal experience. [1]

"Peace and security"—it is difficult not to feel a twinge of nostalgia as these words ring in our ears. There is little peace in Academia these days; and no security save that which we earn by a vigorous defense of rationality and a willingness to give up any particular items of belief that prove wanting in the face of critical questioning. Peace is not for our generation, but we can survive. More than that, we can change the world—and it is change that is demanded once we ask, "What is the relevance of our specialized knowledge to the pressing human problems of the day?" The ivory tower is gone, and we have become agents of change.

Nowhere is fundamental reform more necessary than it is in the area of population. The development of death control in the last five generations has made attitudes that were adaptive for three thousand generations now maladaptive. Now—*and from here on out.* The seemingly boundless frontier is gone, and suddenly we realize we are crammed into a spaceship. With a diameter of almost eight thousand miles our ship is somewhat larger than an Apollo craft that holds three men, but in principle it is no different. In the face of the explosive power of exponential growth what difference does it make whether the diameter of the space craft is 20 feet or 21 million? Very little. In either case it is finite. It is not expanding. It can hold only so many people. The inhabitants of a spaceship are surrounded by an effluvium of their own waste products. Recycling is a necessity. Above a certain level of population—which we no doubt passed some time ago—the greater the population, the worse the environment in the spaceship. [3] If we want to live in dignity, we must find a way to limit the number of passengers on our fragile craft.

At the moment we are completely failing in this task. Fourteen years ago

Dr. Hardin is professor of human ecology, University of California, Santa Barbara. This paper was presented at the banquet session of the NSTA Convention in Washington, D.C., March 28, 1971.

the population of the world was increasing by 123,000 *a day*. [9] Now the increase is 190,000 per day. Next year it will be greater.

Think of it: an increase of 190,000 per day. That's 2.2 more persons alive every second. Each time you take a breath 13 more people are stressing the inadequate resources of our little craft.

That's no way to treat a spaceship.

WHAT are we to do? Whenever we human beings are faced with a hard decision, our first impulse is to run away. Population control is a hard decision. True to form, we try to run away from the problem of controlling population. Some of us say that we don't need to worry about the finiteness of the earth because we can always ship our excess population off to other planets.

Unfortunately not one of the other planets of our solar system is anywhere near as suitable to human existence as is Antarctica or the top of Mt. McKinley—and there's no sign of a real estate boom in either of those two desolate places. Denied escape to the planets of our own sun, we find the next *possible* refuge to be at least 4.3 light-years away—that's 25 trillion miles. The triple sun Alpha Centauri *might* have some planets suitable for human life. Again, it might not.

Consider the expense of such a migration out into space. A number of years ago I calculated roughly the cost of shipping people off in a suitable spaceship, minimizing costs outrageously to give the opposing view every possible advantage. [4] It came to $3,000,000 per earthly emigrant.

To keep the earth's population from increasing beyond its present level you would have to ship off 190,000 people every day. That would cost 570 trillion dollars *per day*. The GNP of the United States still has not reached the level of one trillion dollars *per year*.

Well, it was a good try.

SO space is no escape. What next? The next evasion is birth control. Does that statement surprise you? If it does it is because you equate birth control with population control. This equation is part of the "conventional wisdom," to use Galbraith's term [2], the wisdom that is almost right but not quite. Ninety-nine people out of a hundred think birth control *is* population control. Ninety-nine people out of a hundred are wrong.

It takes a hammer to build a house, but who would equate a carpenter's tools with architecture? Similarly, birth control is merely a tool with which population control *may* be achieved—but again it may not. It depends on what you use the tool for.

A simple systems analysis of the population problem will help make this clear. The principal actor (or rather actress) in the drama is the woman. It is she who produces the children. Men are needed too, of course, but they are so ubiquitous and so readily available that it is safe to think of spermatozoa the way we think of air and water—as nearly always available, and virtually free. Systematic analysis is best focused on the woman; she is the most powerful agent in population production.

The birth-producing system can be decomposed into elements of Message, Reception, Performance, and Results (see Table 1). The target of the system, the woman, receives many messages—from her parents, from her friends, from her religion, and from society at large. Let's see what some of these messages are, taking them one at a time, and deducing their populational consequences. To begin with we will assume that the reception of the messages by the woman is perfect and that she uses a perfect system of birth control.

One message the woman might receive is "Stop at two," which is the message of the ZPG people (Zero Population Growth). If all women received and acted on this message a stable population would ultimately result, because the amount of increase is zero. (In our rough analysis we ignore minor effects like celibacy and sterility on the one hand, and multiple births from second pregnancies on the other. Perhaps these would balance out.)

Suppose the only message a woman received was "A boy for you, a girl for me,"—which you may recognize as from the musical comedy, *No, No, Nanette*—what would be the populational consequences of this? If she and her husband decide they won't stop breeding until they have produced one of each, how big will their family be? Probability enters at this point; it turns out that the average family will have approximately three children in it. The population will increase 50 percent each generation. (The U.S. population is increasing not quite so fast as this now.)

Let's try another message. Talking with many educated people in India recently I became convinced that the message most commonly heard by an Indian woman is this: "An heir and a spare." Immersed in the Indian culture, it seems essential to her that she have at least one son; and prudence dictates two, because one may be lost to disease. Given the directive to keep producing until she has two sons, a woman will produce on the average approximately four children. India's present population growth rate—2.5 percent per year—is about what you would expect from adherence to such an ideal, assuming most of the children are produced early in a woman's breeding years.

In the light of these mathematical

Table 1. A systems analysis of population growth.

Message	Reception	Performance	Result	Increase
Society's Directives, Implicit or Explicit	Precision Assumed	Effectiveness of Birth Control Assumed	Approximate Average Number of Children per Family	Factor of Increase per Generation
"Stop at Two"	Perfect	Perfect	2	1 (ZPG)
"A boy for you, a girl for me"	Perfect	Perfect	3	1.5
"An heir and a spare"	Perfect	Perfect	4	2

relations let's ask, "What *is* the population problem?" Conventional wisdom thoughtlessly presumes that all we need to solve overpopulation is birth control. "If only we had a better method of birth control," people say, "we could bring population growth to a halt." But the results indicated in Table 1 assume a *perfect* method of birth control—only the first message produces ZPG. Neither of the other messages does, and these messages circulate widely throughout the world. These messages are received and acted upon. The message "Stop at two" is still very uncommon among the world's 3.7 billion inhabitants.

Let's look at the matter another way. Suppose the commonest message in a society is the second one, "A boy for you, a girl for me." With a perfect system of birth control, three-child families would be the average. Such a perfect system is within our reach in the United States: the perfect system consists of contraception, plus abortion as a back-up for contraceptive failures, to be followed by sterilization after the reproductive goal has been reached.

But some Americans are reluctant to employ abortion and sterilization. The reluctant fraction of the population is rapidly diminishing, but let's put that fact aside for the moment. Suppose abortion and sterilization are rejected and only the best method of contraception is used: How serious would its imperfection be?

HOW reliable is the contraceptive pill? Christopher Tietze [10], the leading authority in this matter, says that it has an intrinsic failure rate of only 0.1 pregnancy per hundred woman-years of exposure to the risk of pregnancy. Much higher failure rates than that are probably due to "forgetting," to a woman's ambivalence about taking the pill. In such cases, it is not the Performance of the technology that is at fault, but the Reception of the message. Since I am concerned here only with the consequences of Performance errors, I will take 0.1 percent per year to be the intrinsic failure rate of the contraceptive pill.

Suppose a woman elects to have three children, and relies entirely on the pill for birth control: How many children will she probably have? Method failures *before* she achieves her goal produce only failures in spacing, not in number; so let's focus only on method failures taking place *after* she has achieved her goal of three and see what the populational consequences will be.

Assuming she has the desired three children by the time she is 25 years old, she now has 20 years of risk ahead of her. If she uses the pill, and if we assume the risk rate is 0.1 percent per year, she will (statistically speaking) produce 0.02 of a child more than she wants in her remaining fertile years. Following the directive, "A boy for you, a girl for me," and using a birth control method that is 99.9 percent perfect, women will produce an average of 3.02 children each, instead of an average of 3, as they would if they used a perfect method.

But the number desired (3.0) is much greater than the number needed for ZPG. Because of mortality, celibacy, sterility, etc., the true ZPG number is not (contrary to Table 1) 2.0 per woman, but closer to 2.11 per woman in the U.S. Women who produced 3.02 children would exceed the ZPG number by 0.91 child. To what should we attribute the excess over the ZPG number?

The excess can be divided into two portions:

a. excess due to error of method = $.02 \div .91 = 2\%$ of excess
b. excess due to error of goal = $.89 \div .91 = 98\%$ of excess

Now we see why fretting about the technology of birth control is a way of running away from the population problem. A birth control method that is 99.9 percent reliable is really good enough. Why knock ourselves out to improve it? If too many babies are being produced it is because the method is not being used, whether out of ignorance, fear, or prejudice; or because individual women want more babies than are needed on a spaceship. In any case, the problem of population control is not a technological problem, not in the ordinary sense. It is a problem deep in the minds of women and men.

WE run away from hard problems—and try to hide our cowardice from ourselves. Let me illustrate this point. At the end of 1970 the Department of Health, Education, and Welfare put out a little booklet entitled "The Federal Program in Population Research." [11] It claims that the total funds allocated to population research in 1970 amounted to 163 million dollars. Sounds fine. At last it sounds as though we're doing something about population. But are we?

Burrowing around in the tables, one finds that 80 percent of those millions went for "Data Generation and Compilation Activities." What does that mean? Well, 96 percent of *that* money went to the Department of Commerce, and you know what it was used for: the Bureau of the Census. Is that population research? If putting out a telephone book is carrying on research in information theory, then census-taking is population research. That's stretching the meaning of population research too far. But it looks nice in a government report.

What about the remaining 20 percent, 34 million dollars, which might classify as population research? It's risky trying to deduce the contents of research programs from their titles, but perhaps we can reach a first approximation to the truth. Looking over the printed titles, I estimate the projects can be assigned to the categories shown in Table 2. Out of every thousand dollars spent for population research, only about two dollars seem to be aimed at altering the population message or improving the reception of it. Perhaps as much as 110 dollars—certainly no more. The rest is spent on trying to improve the performance of already excellent methods of birth control.

Table 3 puts the matter more bluntly. We spend 89 percent of our money to tackle only 2 percent of the population problem; by contrast, to 98 percent of the problem, we allocate at most 11 percent of the money, and maybe as little as 0.2 percent.

We've got our priorities mixed up. We had better stop running away from the problem.

SUPPOSE we do stop running, what then? What can we do? I don't know; I don't think anybody knows for sure. But I think we must make a beginning with the Message.

Some of the messages children are getting are utterly unsuitable for people living on a spaceship. Among contemporary children's books I know of no more sinister example than one called *Always Room for One More*. [7] The writing and the art work are of the highest quality, but the message is vicious. Don't worry, it preaches, we always have room for another person; isn't this crowding jolly? . . . This benighted book was published in 1965, four years after Yuri Gagarin became the first traveller in a man-made spaceship. The author had apparently not yet caught the insight into human problems generated by the space effort.

I don't know how many children have read this immoral book; not many, I hope. But millions have read the lower-key Dick and Jane books. Remember them? They had a population message in them too, though I'm sure the authors were unaware of this fact. The neighbors on the left had children; the neighbors on the right had children; the ones across the street . . . in fact, all God's chillun had chillun. Nothing else was conceivable. Exposed at a tender age to such a message, what is a little girl to conclude? Plainly that she just has to become a mommy when she grows up. Nothing else is normal. That's the message of the Dick and Jane books.

I think it's time to change the message. I have suggested [5] that we augment that message with another one, a contradictory one. Let us introduce the first-graders to delightful Aunt Debbie—forty years old, pretty as a picture, fond of men, and fond of children (but only in small doses). She is a working woman and likes her job. She likes her freedom. The children just love her and look forward to her visits.

Jane, in the depths of her subconscious, wonders whether she wants to be like Mommy when she grows up, or like Aunt Debbie. She doesn't know. She just doesn't know.

And she shouldn't, not at her age. Let Jane grow up hearing *two* messages: being a Mommy is nice—but so is being a Debbie. Let her find her own identity. Later. And let society make it possible for her to live a psychologically rich and respected life if she decides that parenthood is not for her. We will all benefit if women are freed to find their own identities and not pressured into having children needed neither by them nor by society.

The major population problem immediately ahead of us is educational, not technological. In the elementary grades we must keep the option of childlessness alive in the child's mind. At the secondary level we must display a wide spectrum of enticing vocations available to nonparents. A significant part of our success in population control will come as a "fall-out" from persuading *and making it possible* for more women to become scientists, artists, machinists, business women—the list is endless. It even includes work in the nursery—the community nursery, that is—as professionals in child care. We not only have too many children, we have too many poorly taken care of. We need to *pay* women to fulfill this role, so important to the nation, instead of expecting them to be unpaid slaves. Paradoxical as it may seem, if we pay them well for taking care of children they will probably breed less.

We live on a spaceship. There are too many of us. Some of the decisions we will ultimately have to face [6] may require a long political reorientation first. [8] But it is possible even now to begin on the challenging task of educating our children so that our grandchildren will live in a spaceship less crowded than ours, and live a better life. Let's get at it. ☐

Table 2. Allocation of federal funds for population research in 1970.

CATEGORY	PERCENT OF FUNDS
Performance research (birth control, delivery of services)	88.9
Uncertain classification (academic sociology)	10.9
Message and *Reception* research, apparently	0.2
	100

Table 3. Allocation of federal funds nearly irrelevant to population research needs.

	MESSAGE AND RECEPTION AREAS	PERFORMANCE AREA
Distribution of the money	0.2% - 11%	89%
Distribution of the problem	98%	2%

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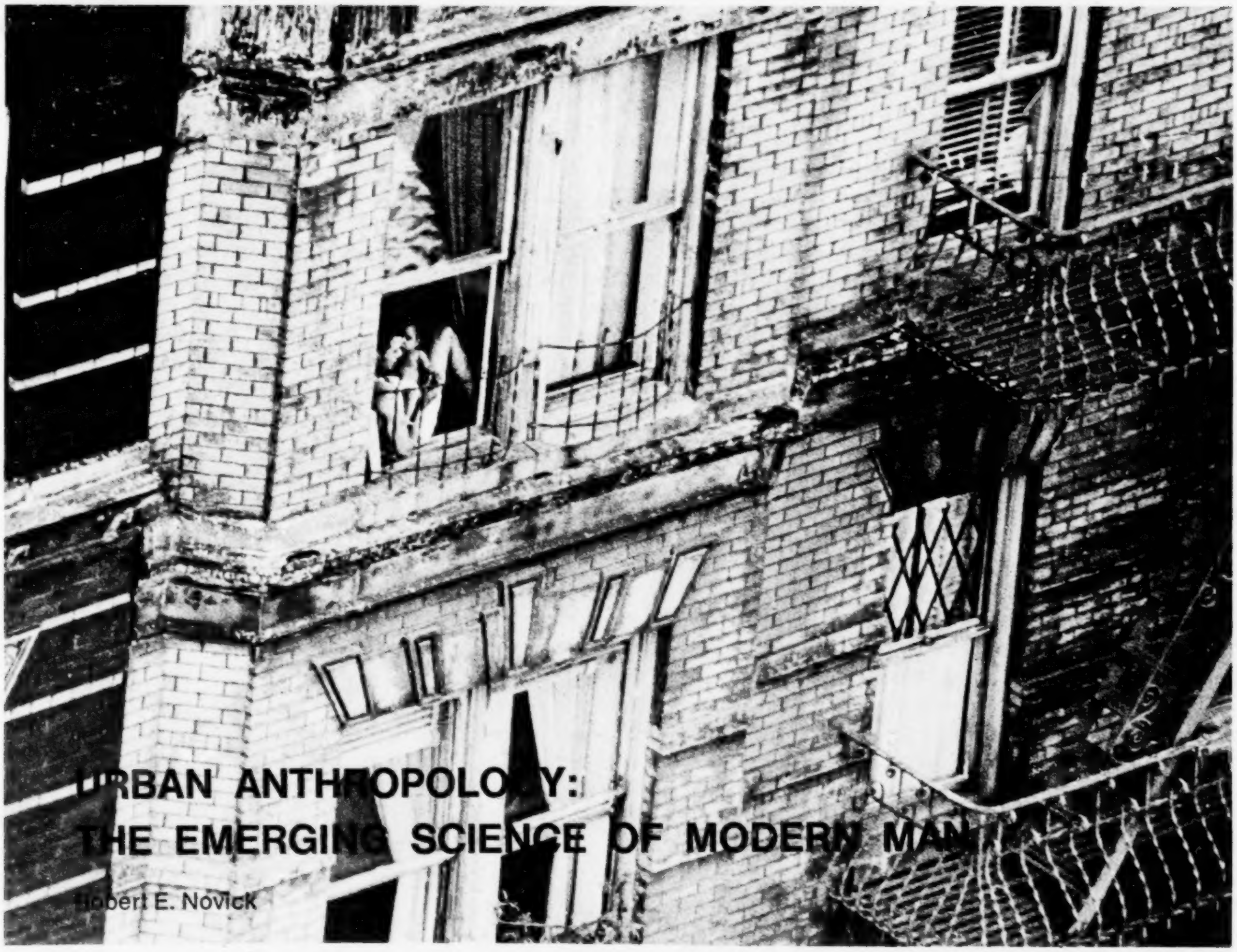

URBAN ANTHROPOLOGY: THE EMERGING SCIENCE OF MODERN MAN

Robert E. Novick

PHOTOS, U.S. BUREAU OF OUTDOOR RECREATION

THE term ANTHROPOLOGY often conjures up an image of scientists in pith helmets filming the tribal rituals of remote natives.

While the study of primitive and ancient peoples has added immensely to the understanding of man and the growth of culture, modern civilization is in trouble. Today, in spite of the tremendous advances in technology over the past century, man struggles through crisis after crisis in a world filled with anxiety and hate, crime and violence, starvation and ill health. We apparently know far too little about population dynamics; about increasing agricultural production; about the pollution of air, water, and land; or about the chronic physical and mental disorders affecting large segments of society. The widespread use of drugs, alcohol, and other "cultural chemicals" reflects personal frustration with the great social disorders in the human settlements of the world.

Rapid increase of the global population in recent years has intensified stresses on man and his environment.

Projections indicate that the population is likely to double in 30 years to 6 billion by the year 2000. There may be 25 billion people on earth by 2070, less than two life spans away.

As our numbers grow, we tend increasingly to congregate. By 1975, according to United Nations estimates, 44.3 percent of Europe's population will be living in localities of 20,000 or more. In the United States by 1980, more than half the population will be living in the 52 largest metropolitan areas, compared to 45 percent in 1960. Of the world's 36 largest urban agglomerations, nearly half (17) are in developing nations where the quality of life is less than in the advanced nations.

The plight of today's cities and of their inhabitants can be attributed to a familiar pattern of problems—poverty, unemployment, crowding, pollution, poor housing, unsanitary conditions, alienation, and, for many, a low educational level. Urban crowding has been related to high infant mortality rates, higher admission rates to hospitals for contagious diseases, meningococcal disease, anemia, respiratory and digestive diseases, and a variety of heart and circulatory diseases. It is associated with increases in the rate of household and traffic accidents and accidental poisonings. Crowding has been causally linked to alcoholism, drug abuse, and a host of diagnosable mental and behavioral problems.

Yet, the masses continue to crowd into the urban areas. Despite the poor social and economic conditions concentrated there, rural-urban migration

Mr. Novick is the director of the Bureau of Community Environmental Management, Health Services and Mental Health Administration of the U.S. Department of Health, Education, and Welfare.

continues. And those who live there remain.

The poles of attraction are strong. Cities are "where it's at" in terms of jobs, culture, education, entertainment, people. Despite their shortcomings, cities offer a broad diversity of advantages not available in rural areas: more medical care facilities, environmental sanitation, welfare, a variety of recreational and entertainment activities. There are also more professionals per capita in the cities than in the country.

Unfortunately, the growth of the cities has taken place without proper consideration for or application of principles gained from the study of man. Planning has been neglected. Development has taken place piecemeal, with regard primarily to land use economics, with little thought to the personal and social needs of the inhabitants or the total cost to society if those needs are not met.

The ultimate impact of this uncontrolled development is not known. But statistics on disease, the growing social disorder throughout the world, and empirical observations of human behavior strongly indicate that mankind is heading for monumental disaster unless he learns more about himself.

AS THE cities have grown and spread, governments have tried to grapple with the stresses on modern man in his new, self-made environment. Entire networks of services, including education, consume the biggest part of the domestic tax dollar, not only in the United States but in many of the developing nations as well.

But the results of these programs cast serious doubts on their effectiveness. Advanced nations like the United States are still plagued with spiraling unemployment, growing numbers of people requiring support from public sources, rising costs of health care, increasing pollution, and more crime and social disorder.

Much of the effort by government has been aimed at the provision of better housing. As civilization has progressed, more and more of man's needs have been met in the design of shelter and its components. Man has engineered an entire artificial environment which provides filtered air and water, a normative temperature, and adequate light. It is possible to design out noise and insect pests, provide refrigeration and cooking facilities for food, and develop systems to rid the immediate environment of sewage and solid wastes.

Even with all of the available technology, large portions of the world population and a significant number of Americans do not enjoy its benefits. There are, for instance, nearly 12 million crowded, substandard dwellings in the United States, about 15 percent of all available housing. Four million of these units lack one or more essential indoor plumbing facility; nearly 3 million are in such poor condition that they cannot be rehabilitated without major repair.

About one-third of all nonfatal injuries occur in and around the home. Poor housing creates many unhealthy conditions: 25 million home accidents in the United States each year are caused by faulty electrical connections or appliances, poor lighting, broken furniture and equipment, and dilapidated stairs, floors, and walls.

Additionally, there are 60,000 cases of rat bites and 6,000 cases of rat-transmitted diseases a year; 3,000 deaths and 1 million injuries from accidental poisonings of all kinds, due to inadequate storage facilities in the home as well as inadequate safety consciousness; 400,000 children with unacceptably high levels of lead in their blood from ingestion of lead-based paint chips in old, unmaintained apartments and homes; and at least 1,000 deaths and 5,000 injuries from carbon monoxide poisoning caused by improperly constructed, installed, or maintained home heating devices.

Landlord abandonment of buildings, widespread dilapidation, abuse and vandalism of structures, and the associated health effects are problems characteristic of the inner city and rural neighborhoods alike. Deterioration and poor sanitation provide a depressing setting for life.

Major efforts aimed at solving the problems of the urban environment have centered on a number of areas which were thought to be directly responsible for the problems of the city. Massive urban renewal campaigns begun in the 1960s were to provide housing for large numbers of people. More and more social and welfare services have been offered.

Yet, these efforts have met with only marginal success. Many a major urban renewal project has fallen into disrepair within the first three years of occupancy. And the cities have been increasingly plagued with a variety of social disorders.

More recently, the government has focused on restoring the quality of the physical environment, attacking air and water pollution, solid waste, noise, radiation, and other hazards to man. The thrust of the programs of the new Environmental Protection Agency has been to clean up the natural, outdoor environment—the rivers, the landscape, the air.

ONLY lately we have begun to recognize that perhaps the most vital part of man's environment is his man-built world: the place where he works, his home, his neighborhood, his community. Today, people spend at least 80 percent of their entire lives indoors.

Congress and the Administration have recently come to grips with the potential problems of the man-built environment, the ecosystem of human settlements. The Bureau of Community Environmental Management (BCEM) of the Department of Health, Education, and Welfare has been assigned responsibility for many aspects of urban environmental health—among them, rat control, lead-based paint poisoning, home accidents, and pedestrian safety.

BCEM has been working with a small but growing band of investigators searching for more meaningful answers to complex urban problems. Drawn from a variety of disciplines, shifted from a number of study areas, this small corps of scientists is emerging in a field which can aptly be called *urban anthropology*. These researchers are concerned with the study of man—modern man in his contemporary urban environment—from biological, psychological, and social perspectives.

Nearly 12 million dwellings in the United States, about 15 percent of all available housing, are crowded or substandard.

Through a variety of studies we are attempting to understand more about man's needs as he perceives them. From these studies we are beginning to piece together some of the root causes of health problems and social disorganization and alienation which characterize many human settlements.

We are beginning to understand from these new studies that many, if not a majority, of acute and chronic diseases in man cannot be properly explained by a direct relationship to single causal organisms or physiologic defects. Even in the area of infectious disease, microbiologists now recognize that man in the natural environment is everywhere exposed to potentially pathogenic organisms, while only infrequently is he overcome with illness. While man is born with a fixed genetic endowment, he is highly susceptible to the stresses of life—physical, biological, psychological, social—which can precipitate clinical disease. It is possible, we feel, that diseases like cancer, arthritis, emphysema, diseases of the central nervous system, mental disease, tuberculosis, and other infectious diseases may all have long dormant or latency periods during which the normal body responses compensate or hold in check the incipient disease. At some time in man's life, apparently, the balancing force is overcome and clinical disease begins.

That social stresses can stimulate a variety of diseases—physiological and behavioral—is indicated by recent epidemiological studies showing that the frequency of disease, especially some of the chronic, degenerative, and mental disorders, is highest in urban settings, particularly in crowded inner cities and in areas housing migrant populations attempting to acclimate to urban life.

Research is now focusing on the relation of health to the pattern of relationships that exist in the residential environment. Animal studies indicate that crowding and lack of territorial control leads to marked and persistent hypertension, increased maternal and infant mortality, reduced resistance to bacterial infections, and decreased longevity. Changes in group membership and the "quality" of group relationships have been shown to be accompanied by neuroendocrinal changes, including major changes in the hormone balance of the body. These changes can markedly alter the balancing mechanisms of the body and the responses to a wide variety of stimuli.

What this means, obviously, is that if man's responses are similar to those of experimental animals (and we have strong reason to believe they are) many of the health problems of the alienated, the poor, and those in overcrowded and dilapidated housing and neighborhoods are caused by pollution and other physical problems reinforced by the gross lack of meaningful social life.

With urbanization, people have become increasingly exposed to the social processes which can cause health problems. Urban crowding and interruption of social activities create tensions which, when prolonged, cause anxiety, alienation, and apathy. When people become apathetic they display indifference toward their neighbors and community. Apathy is a major cause of pollution and urban decay. It means that the homes will deteriorate from abuse and lack of repair. It means withdrawal from school, from responsible involvement in the community and from society. Apathy leads to a host of maladaptive social behaviors: drug abuse, crime, sexual deviation, violence, and destruction of private and public property, even of the individual himself. The result is the tearing down of both the physical and social structure of the human settlement.

LITTLE is known or understood about the processes that result in this social decay. We need to find ways to interrupt these processes or to turn them to positive outcomes.

Our studies indicate that part of the solution is careful design of the dwelling to provide adequate space for each

PHOTOS, U.S. BUREAU OF OUTDOOR RECREATION

New York City dwellers find opportunities for relaxation and recreation in city parks and fountains; in blocked-off street sections; and in "pocket" parks, such as Paley Park (lower right). Lower left, an elderly woman finds solitude on a rooftop.

PARKS, RECREATION AND CULTURAL AFFAIRS ADMINISTRATION.

individual, along with a "sufficient" amount of privacy. It has been shown in Europe, for instance, that the tension buildup in the dwelling during the course of a day is likely to lead to abnormal behavior which can harm the family or the individual unless there is at least 80 square feet of living space per person. In cases where there is an incapacitated person in the household, however, 130 square feet per person is required. This finding is significant for the design of housing units which might accommodate sick or incapacitated persons.

Obviously, other design factors of the dwelling can also help relieve tension of daily living: proper cooking and eating facilities; adequate sanitation facilities; good lighting, heat, ventilation, and soundproofing; clean, modern furniture in good repair and adequate conditions of the dwelling, including safe stairs and floors, electrical equipment, and clean, painted walls and ceilings.

But the environment in which modern man lives is not merely the dwelling. It is necessary that man get away from his work place or home for part of his relaxation, entertainment, and cultural pursuits.

Man needs and seeks a variety of forms of relaxation and relief from tension.

In established communities with strong social ties, tension can be relieved by visits with a neighbor or relative or to the local recreational or entertainment facility where there are familiar faces. Alienation can be reduced as these affiliations form the support for changing aspects of community living.

In congested urban areas, where land is at a premium, occupants find shelter where they can, or where they can afford it. Little space is set aside for recreation or cultural activities. The time required to get to available tension-relieving facilities is often too long to encourage more than an occasional visit. Studies indicate that most Americans fail to use facilities which are more than five to ten minutes away from the home.

For certain groups, especially the

aged, scientists working with BCEM have found that facilities and opportunities offered to the community-at-large are not necessarily useful or appropriate. In studies of older residents of the community, for instance, it was found that many of the recreation facilities were "taken over" by young people to the exclusion of the elderly; and the elderly, refusing to subject themselves to the harassment of these younger people, failed to take advantage of such facilities available to them. Many chose self-imposed isolation, rather than face embarrassment or hazard at the hands of teen-agers or young adults.

Far too often, community facilities have been planned without due consideration for the needs or wishes of the various segments of the residential environment. Swimming pools and tot-lots are good for the young. But a quiet corner, a reading room, or even a neighborhood grocery store may be necessary to meet the needs of the elderly. Without full knowledge of the needs of the various segments of society—age and ethnic, social and economic groups—it is impossible to design or plan a community which will serve all its members.

The President's Council on Environmental Quality recognized these problems of urban living when, in its second annual report[1] issued in August, it said:

> The sometimes bitter experience of the past years has taught the lesson that improvements in the daily environment of people must be sought with their help and guidance, not imposed on them by those who claim to know what is best.

But the Council also recognized that:

> . . . Many of the forces that shape the intimate environment of the inner city resident are often beyond his knowledge and control.

The recognition on the federal level of the deep social strife affecting the community is an important first step toward solving these problems. The Council noted that:

> The experience of the past 10 years in trying to deal with inner city problems has demonstrated the need for an approach that fully takes into account the interrelationship among many varied factors. As the environmental perspective of all citizens matures to embrace greater concern for the quality of life, it is hoped that the plight of the inner city may command—in government and in the private sector—more broadly based efforts of a Nation growing more intent upon improving the life setting for people, wherever they may live.

People are individuals, each requiring different services, each with his own goals. The starting point for meeting these needs is in the design of the residential environment and in the education of those who will live there. When we understand people's needs, the physical and social environment can be monitored, maintained, and changed to help reduce undue urban stress.

UNDERSTANDING urban man is the key to providing for his needs. Many of the studies now underway by investigators across the nation are designed to supply the answers needed to "cool" the cities, to alleviate the tensions in the residential environment, to satisfy the needs of the people.

One new program aimed at helping local communities identify their problems and set their priorities is the comprehensive, action-oriented Neighborhood Environmental Evaluation and Decision System (NEEDS) developed by the Bureau of Community Environmental Management. NEEDS is designed to help recognize the cause-effect relationship of environmental and social stresses—pollution, noise, crowding, poor housing, and neighborhood instability—and individual health, both physical and mental. NEEDS uses locally recruited residents trained to interview families and groups about their perceived needs and their neighborhood environment. Thus, the NEEDS program gives the community back sufficient information to analyze both the severity of existing problems and the areas of potential crisis before the crisis occurs. Several other community-based organizations are now developing innovative programs, aimed at comprehensive environmental improvement in inner-city areas.

Years of experience trying to deal piecemeal with inner-city problems have shown that solutions lie only in a fully integrated approach, taking account of the interrelationship of many varied factors. We must learn more about modern urban man.

The teacher's role in this process is vital. As society becomes more aware of its problems, it becomes increasingly important to understand human ecology and the human environment. As teachers attempt to add environmental concepts to their programs and plan more and more interdisciplinary work, they must become more aware of the advances made in the field of urban anthropology and of the studies of modern man in the urban setting.

There is a small national scattering of courses, beginning at the intermediate level, which involve studies of urban ecology. Some are based in biology, some in environmental science, some in the social studies, some in geography, history, and other disciplines. Wherever the subject falls, whatever the base, there is a need to develop an awareness on the part of the young people of this nation, to help them recognize that in a great many social institutions there is a gross lack of understanding of the environmental, social, and technological forces as they interact to produce ill-health and social disorder. It is important that courses or segments of courses be developed to stimulate this awareness, to help define actions that will correct these deficiencies, to monitor the social, environmental, and technological processes that underlie many of the society's greatest ills.

The Bureau of Community Environmental Management is working with a few schools providing technical assistance for the development of course materials to be used in teaching about the ecology of human settlements or urban anthropology. The Bureau is actively seeking help from teachers and school systems which are developing or have developed their own approach to the subject.

It is obvious that as man's concern for the quality of life grows, more broadly based efforts must be focused on improving the life setting for all people. ☐

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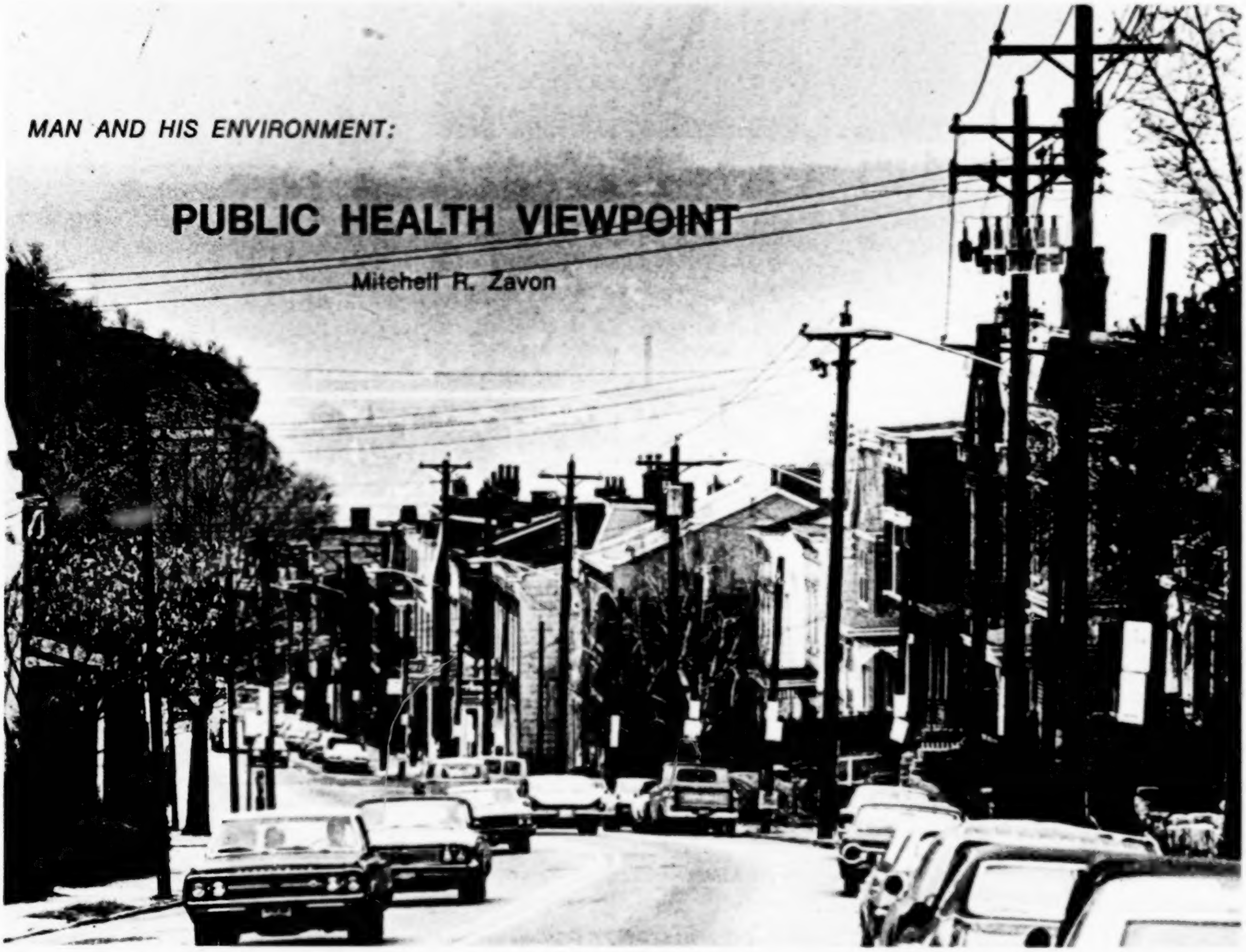
[1] *Environmental Quality—1971*, the second annual report of the Council on Environmental Quality, August 1971. For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402; $2.

MAN AND HIS ENVIRONMENT:

PUBLIC HEALTH VIEWPOINT

Mitchell R. Zavon



ALLAN KAIN, CINCINNATI ENQUIRER

THE women of Schneeberg and Jáchymov in Bohemia used to outlive three or more husbands—men who worked in silver mines from which uranium is now extracted. The Mad Hatter described by Lewis Carroll in *Alice in Wonderland* was a fictional character, but the men preparing felt for hats in Danbury, Connecticut, used to behave in many respects just like those in the Carroll creation. The Schneeberg and Jáchymov miners worked in an environment in which there were excessive concentrations of silica and radioactivity. The hatters of Danbury were following the traditional procedure for making felt, by treating the fur with mercury. In the process they absorbed grossly excessive quantities of the element. These two occupationally induced illnesses are examples of preventable diseases which result from environmental causes. Students of antiquity can document a multitude of diseases caused by the environment; their prevention is a matter of comparatively recent knowledge.

In 1911, Alice Hamilton reported on her survey of occupational diseases. By so doing, she helped to alert our nation to the need for corrective action to prevent needless disability and death resulting from hazardous conditions in industry. In her lifetime, Alice Hamilton, now 101, has witnessed and helped to make many changes in the environment of American industry; and the Congress continues to debate legislation to set national health and safety standards for the protection of the worker.

Looking forward, the road may seem endless. Looking backward is sometimes the only way to appreciate how far we have actually traveled. If we compare the life expectancy of a child born in the United States in 1970 with the life expectancy of one born here in 1770 or 1870, we can see how far we have come. We have added some 30 or more productive years to the life expectancy of the 1970 child in comparison to his forebears. And we have added those years in large measure by improving the environment. Though the prophets of gloom may paint macabre pictures—and we do have a long road ahead that needs considerable improvement—we have come a long way.

WITH regard to further improving our environment, it is time for reform, for rationalism rather than emotionalism. For the rest of this discussion I will show you a public health view of the environment and man's relation to it by considering some of the various bits and pieces that go to make up the environment.

Dr. Zavon is executive coordinator, Miami Valley Project, University of Cincinnati, Cincinnati, Ohio. This article is adapted from one of the NSTA-Sunoco Science Seminars presented at the annual meeting of the National Science Teachers Association, March 16, 1970, in Cincinnati, Ohio.

Water. Aside from air, the most vital environmental factor is water. When Snow removed the handle from the Broad Street pump in London in 1854, he halted an epidemic of cholera and demonstrated the source of the cholera, though it was many years before the causative organism actually became known. Waterborne diseases such as cholera have long been the scourge of mankind. Even today, schistosomiasis, a parasitic disease of man which is transmitted in water with a snail as an intermediate host, is the second most widespread serious disease of man. Schistosomiasis may deny to Egypt the projected benefits of the Aswan Dam and threatens to undermine the benefits of other irrigation projects.

The introduction of water purification is the single most important public health measure of modern times. Water distribution systems were built in ancient times, but purification, whether by chlorination or other means, has been the big advance of recent times.

In large measure we have learned to protect ourselves from waterborne bacterial diseases, though we don't yet know how to protect ourselves from waterborne viral disease, such as infectious hepatitis. I am concerned about the problem of waterborne viral disease because it does not appear to be as amenable to solution and is not as obvious a problem to the public. Of equal concern is the question of chemicals in the water. We are just beginning to really investigate the effects of trace quantities of chemicals in our water. We are also concentrating more attention on the problem of excess algal growth in our waterways.

Water is an essential commodity for man's survival. We must learn to use it and not abuse it, to maintain its quality and maximize its availability. Scarcity of water may force us to make some difficult political decisions, such as the desirability of bringing water to deserts merely because subdividers have sold desert building lots.

Air. Five minutes without good quality air may result in irreversible changes in the central nervous system of man. Moreover, airborne bacteria can cause life-threatening disease, airborne pollen can cause happiness-threatening hay fever, and airborne gases, vapors, and dusts can cause all manner of disease. We talk of air pollution when we should discuss specific pollutants. There is no doubt that excessive quantities of carbon monoxide, sulfur dioxide, and a long list of other compounds can cause illness or even death; but we must find out at what concentrations these compounds alone or in combination cause adverse effects on human health. We have suspicions based on animal investigations and large-scale studies of human populations, but as yet we do not have precise answers. Until we have better information, our aim must be to reduce all types of air pollutants by all feasible means. *Feasible* means will be the bone of contention and it is this sort of philosophical and operational problem which will be the nub of contention in all environmental control arguments. Again, reason, not emotion, must prevail.

ENVIRONMENTAL HEALTH SERVICE

Among the industrial and mining hazards are the diseases brought on by inhaling dust or toxic gases. Proper safeguards are encouraged by the Environmental Health Service, which also researches new sources of risk to the worker.

Food. The third of the essential needs of man, food, is available in unprecedented quantity in this country. At present we need increased attention to food sanitation in all phases of its production, processing, and distribution. The day of the cracker barrel is gone, but so also is the day of the small processor. Most food is now processed in large food plants, so vast numbers of people are affected if there is a break in sanitation at any one point.

In order to make production easier and to improve appearance, palatability, or shelf life, many additives are placed in food. It used to be that preservatives such as sodium benzoate were added without much control of the amount added. With passage of food and drug legislation in 1906, however, the situation improved and has been steadily improving since that time. Gross adulteration of food is no longer commonplace in the United States. Instead, we are now faced with the need to know more about the long-term effects on man of the many additives used in food processing. The public assumes that we know a great deal—or perhaps that we know everything—about common foods and chemicals. Unfortunately, this is a false assumption. In many respects we are ignorant of the effects of many common foods and food additives. That is, we do not know their precise method of action at the cellular level. We must learn more. Don't, however, accept the idea that our food supply is not safe. There is no evidence that this is true.

Planning. Water, air, and food are essentials for man's survival. Survival is a minimum condition, and as we look at our environment in 1970 we must insist on more than survival. Our environment must be planned to provide the varied types of habitat that are desired by man. Unplanned land use results in unnecessary transportation costs, excessive cost for provision of utilities, and may result in an offensive, unpleasant environment. Good planning can avoid a corruption of our environment.

Too frequently, as we attempt to improve the general environment, we are hindered by the Balkanization of many of our metropolitan areas. Air masses do not recognize city or town boundaries any more than do the waters in our rivers. If air and water pollution are to be reduced, political science will frequently be of more importance than physical or biological science, and support of political reform may prove more important than scientific research.

THE following are additional concerns we must deal with. Roentgen discovered X rays in 1895 and introduced a new type of energy into man's environment. The bomb blast at Alamogordo in 1945 set the stage for a wider dispersion of ionizing radiation, and we have been seeking new ways of using this ionizing radiation and nuclear energy ever since. At the same time we have been seeking better methods of protecting the public from the adverse effects of this very valuable discovery.

The pesticide DDT is probably the most valuable invention of the past 100 years in the benefits it has conferred on man. More lives have been saved, more people have been able to work productively because of DDT than because of any other development of our time. Malaria, that ancient scourge of man, has been controlled; and vast areas of the earth previously rendered uninhabitable for man have been opened up for productive use by the application of DDT and other organic insecticides. From the viewpoint of the public health in the 25 years that DDT has been available, there is no question that benefit has far exceeded harm. The questions raised by conservationists, biologists, and others about the effects of pesticides on organisms other than man have put the continued use of DDT and many other pesticides in jeopardy. From the public health viewpoint, it would be disastrous to abandon the use of DDT. We have no adequate substitute for malaria control. Caution should be exercised in urging the abandonment of any pesticide without real evidence of significant harm outweighing benefit. Too many people in this country no longer recognize that food does not originate in the supermarket. It must be grown on farms and transported and stored—subject to attack by insects, fungi, and other pests at every step in the process.

NATIONAL AIR POLLUTION CONTROL ADMINISTRATION

Alexander Hamilton suffers greatly from air pollution. This statue stands one block from the White House in front of the Treasury Building in Washington.

As the population has increased and the standard of living has risen, noise has become more and more of a problem. Hearing loss can result from excessive noise for a prolonged period of time. This type of hearing loss can occur in a boiler factory, a jet engine test cell, or listening to a rock-and-roll band. Lesser noise intensities can be annoying, irritating, or fatiguing. We are just beginning to look at the public health aspects of noise, and we have yet to define community noise limits on an objective basis.

Above all else, the need to stop population growth has become an overwhelming concern of public health and particularly of those concerned with control of the environment. Unless the population is limited, all other problems, including our ability to sustain the present standard of living, become insoluble.

Many other problems also exist. Solid and liquid waste disposal, accident prevention, improved housing—all are environmental problems which deserve hours of discussion. This should suffice, however, to signal the nature of the problems.

ENVIRONMENT has become an emotion-laden term. Pollution is applied to anything that isn't liked. The problems of planning our environment in order to allow man to live in reasonable relationship with the other creatures on this planet have become a matter of widespread concern. Unless the real problems are looked at carefully, critically, and without allowing emotion to become the overriding factor, we may well end up with disaster. If the public health is to be protected, those charged with its protection cannot be unmindful of the needs of other creatures, but the health of man must be primary. Recently the emphasis in our country seems to have shifted to a non-man-oriented concern to a considerable extent. We must once again put man in the center of the stage. We must recognize that we do not have unlimited resources and must use those resources, including our most precious resource, man, wisely.

To be successful in protecting our environment, we must treat the disease rather than the symptoms. At times the changes in our thinking required to treat the disease will be painful. We cannot speak against "air pollution" and not consider the cost of improved public transportation. We cannot speak against unsightly and offensive solid waste dumps without recognizing that corrective disposal action may require transport of waste to your home community or to mine. Above all, we must recognize that improvement of the environment is likely to cost large sums of money—money which will, therefore, not be available to build schools, hospitals, or airports. We will have to make choices, and no choice will be completely the right one. ☐

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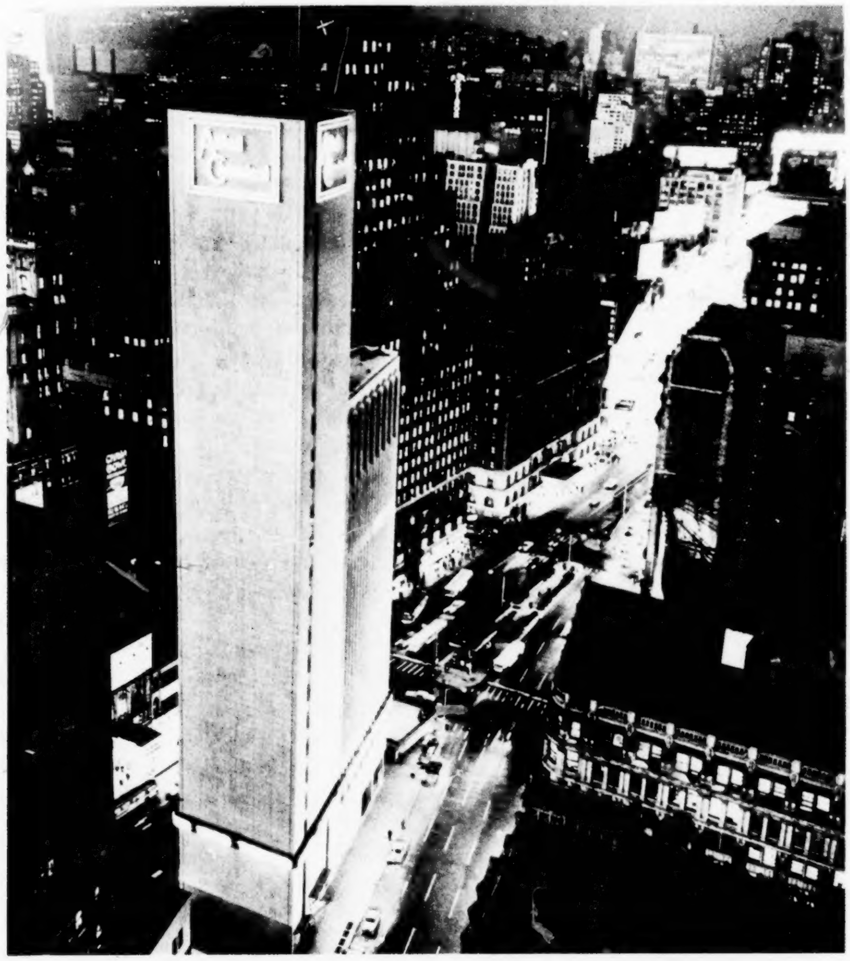
MAN AND HIS ENVIRONMENT:

ONE INDUSTRIAL POINT OF VIEW

R. W. Comstock



ALLIED CHEMICAL CORPORATION

Our enormous production and consumption of electric power contributes greatly to the degradation of the environment. Hard social choices face each of us.

I AM faced with a difficult task, for I am a representative of an industry which, perhaps more than any other in recent times, has been cast in harshest terms as a wanton despoiler of our environment. In the minds of many, electric utilities wear only black hats. Indeed, to an increasing number of people, all industry can be collectively lumped together as "bad guys." While I may not change that opinion, I'd at least like to share one man's perspective with you.

This seminar itself is one indication of the extent to which the issue of environment has come to dominate public and corporate conscience. This concern clearly reflects the winds of change blowing upon the entire electric industry and indeed upon many industries and institutions, including education. I want to discuss three aspects of this new impact of environment on our institutions. First, I will make some guesses as to why environment has become a national issue. Second, I will suggest why utilities have been in the forefront of this crisis. Third, I will indicate the lessons we must apply from today to tomorrow (and these lessons apply equally to education).

To begin, then, why the concern about environment? What are the dimensions of the issue? Where are we going with it? I want immediately to establish that part of my viewpoint which rejects science as being of primary importance in developing solutions to environmental problems. To speak bluntly, the current preoccupation with science (and its teaching) gets in the way of and is an impediment to environmental problem solving. I am deliberately being somewhat extreme, but let me try to rationalize that position.

Among our major environmental problems, with rare exception, we already know what to correct and how to correct it, in a technical sense. We largely know what causes air pollution, where most of it comes from, its components, and the available corrective methods. The same is true of water quality. While there surely is much to be learned about ecological cause and effect, I still ask: How much more do

Mr. Comstock is director, Environmental Affairs, Northern States Power Company, Minneapolis, Minnesota. This paper is adapted from one of the NSTA-Sunoco Science Seminars presented at the annual meeting of the National Science Teachers Association, March 15, 1970, in Cincinnati, Ohio.

we really need to know about the environment to effect technologically sound solutions? Very little, I submit.

A great deal of our energy and time is spent establishing and re-establishing the fact that there is an environmental crisis. Admittedly, the process of stating and restating problems is much more fun than being hopeful, and it certainly is easier. But I think it is time we pull up our socks and get on with problem solving. We all agree the barn is on fire, perhaps it is burning down. Let's get the bucket brigade going. Attention has too long been diverted from the more fundamental questions: how to implement what we already know and how to choose rationally among technical alternatives and their alternative costs. The process of choosing does not involve science. It is political and social. Let there be no mistake about that.

The scientific community must bear part of the responsibility for diverting public attention and the public conscience from the social choice process. By the same token, the scientific community has the opportunity and indeed the responsibility to help direct our public and private concern to the arena of social choice. This responsibility falls particularly upon educators.

If the next generation is to avoid some of our current mistakes, they must have a perspective of the problem-solving process not commonly found today. How many schools today integrate the scientific aspects of environmental education with social studies—in the sense of developing student awareness of the whole range of restraints involved in environmental decision making. These include scientific restraints to be sure, but they also involve political, social, economic, and legal restraints. Solutions to environmental problems do not occur in a vacuum. Are we really teaching that technological answers are just the beginning—not the end—of the environmental problem-solving process? This is a concept that is hardly perceived at all by the general public.

All of us, but particularly educators, must recognize that the environmental problem is essentially a social choice problem. We must choose among alternatives and do so fairly soon. But unless society has goals specified at the time we turn to the technicians, we are in danger of placing the problem in the hands of people who are simply not trained, not committed, and not charged with the responsibility for making social choices.

Minnesota is now faced with just that problem. U.S. Steel has a large manufacturing plant in Duluth which is in violation of the air quality standards recently established by the Minnesota Pollution Control Agency. U.S. Steel has clearly stated that the plant is now only marginal, and it may close the plant down rather than add several million dollars in stack emission equipment. Duluth, although a large city, is in a rather remote part of the state. It has severe financial problems. The U.S. Steel plant employs over 2,500 people, and the loss of the plant would be a crippling blow to the city and probably to the economy of that part of Minnesota. If the people of Duluth were to decide, they might well choose to accept the plant as it is. The decision whether or not to require compliance clearly involves a social choice. We all know who will decide this question (the Pollution Control Agency), but the real question is who *should* decide—the people of Duluth, the people of the State of Minnesota? Should Wisconsin inhabitants, whose environment is affected, have some input? On what basis should a decision be made? These are hard questions; not only are there no answers at present, there are not even mechanisms to search for answers. Soon, we *must* be able to answer such questions.

IT'S FAIR to say that we get "hung up" because we really don't have any established forums for this kind of problem solving. Historically, our major problem-solving institution has been government. Yet, by and large, there has been a failure of government on all levels to produce bold and thoughtful solutions to environmental problems. The reasons for that failure are complex.

In part, it is the product, in Minnesota at least, of extreme government proliferation, particularly in the metropolitan area. For an extensive transmission-line system within our state, we had to deal with 127 separate governmental units, each one having a blackball capability. To expect comprehensive planning, to expect sound decision making to occur in that kind of fragmented governmental scene is, of course, foolish.

In part, the failure of government is attributable to the general public, to the press, to the environmentalists, and, yes, to industry, because we often do not permit government to act in a responsible and responsive manner. I urge you and your students to attend a meeting of some governmental forum where environmental decision making is going on, be it at local or state level. I predict you will be appalled, for often these meetings look like an SDS meeting out of control. We don't give government a chance to function. If that is to change over the long run—and it surely must if we are to survive as a people—the educational system must impart an understanding of the problem-solving process, both in terms of its weaknesses and its strengths.

ONE FINAL shot at science. You may be astounded to learn that people like me—a nonscientist, a layman—find it easy to believe that just around the corner is some new magic which will enable me to avoid making hard social decisions. I can continue to drive my car wherever and whenever I want, because science soon will produce the electric car, or a new engine, or electronically guided highways. Maybe I won't even have to travel at all. Perhaps, I can sit at home and conduct my business over the tube.

I am reminded of a theatrical device used by ancient Greek playwrights. Their plays were long, and plots became terribly complex. In order to conclude within a reasonable time, the Greek playwrights developed the so-called *deus ex machina*, a machine of the gods which descended from the heavens in the third act and in a twinkling set everything aright. There is danger that idolatry of science will lead too many of us to wait for the last scene of the third act for the plot to be straightened out. But there are no miracle solutions. There are only hard choices—hard choices for me, for you, for my corporation, for all institutions.

LET me play a game of semantics with you. There probably is an "environmental crisis." Most of the major writers with science backgrounds seem to agree on that. They agree on the inevitability of results, assuming continuation of certain current conditions. They *disagree* on the time scale within which those results will occur (ranging from a generation or less to several thousand years). They *disagree* on the reversibility of results, even assuming certain current conditions can be changed. So while it is clear that we probably have an environmental crisis, the precise factual edges get fuzzy.

However, it is undeniably clear we are smack-dab in the middle of a "crisis *about* environment." I speak now about feelings and attitudes—not facts. We don't hear or read much about this aspect of environment—how we feel about it, what its emotional and attitudinal dimensions are, and how these affect the problem.

We must start talking about environmental concern for what it is—an attitudinal set, a feeling. It is a social movement with all the force for revolutionary change that concept implies. If we fail to recognize this, we'll blow it. Let me tell you how I see the crisis about environment, as a social movement.

It is clear that the United States (indeed the world) is in the throes of a massive revolution on many fronts. We are besieged by a host of problems too complex to understand and too remote for us to manage or influence—Vietnam, poverty, inflation, racial tension, to name but a few. To many, it seems like a world out of control, or at least out of our individual control. We are uneasy.

Now place the problems of environment within this context. Here again, it seems as though the world is out of control. But this time the issues are easy to understand, and the solutions seem comparatively simple. Further, the crisis does not relate to some remote part of the world. It is *my* air being fouled, *my* water being polluted, *my* horizon being cluttered. I think it it is clear that the tremendous concern about environment acts as a relief valve to express frustration about the way things are generally. It is a deep-seated expression of a compulsive need to put at least a part of the world in order. The frustration of nonaction becomes intolerable.

Even on the environmental scene, the bad guys are hard to identify. The municipality 20 miles upstream which discharges raw sewage into my river seems remote. The thousands of cars and the burning trash barrels are nebulous targets. But, a major corporation or industry or government is an ideal target, for it can be identified. Further, it is an institution, and for one of the little guys whose world and life are increasingly being managed by others, it is imperative to shake the foundations. Then too, a public utility in a sense belongs to everyone. Each month, over a million people send us payments. Most feel that such payment entitles them to pass judgment on the way we conduct the business.

Somewhere in this perspective we must include youth. A significant segment of the young generally care very little about history or tradition or institutions. Almost all young people want a better world, and they want it now. Thus, our time has been characterized as one of noninvolvement with established society and of anti-institutionalism. Margaret Mead in *Culture and Commitment* points out that for the first time in the history of man, change and rate of change are so rapid that there is little that is historically relevant which an older generation has to pass on to the succeeding generation in the way of morals, tradition, or custom. Even the facts we teach have an increasingly short life.

We see clear signs all around us. The structure of the political system is rapidly changing. The institutions of education and of organized religion are undergoing transformation. The young and, increasingly, the not-so-young are rejecting traditional solutions, institutions, and values. *This is the real revolution!* This is the real credibility gap—the gap between an ordered society and those who reject not only the solutions but, more importantly, the problem-solving mechanisms of the ordered society. We are thus experiencing on all fronts a withdrawal of toleration for inaction, an impatience with dialogue unaccompanied by concrete results.

WHY IS the electric industry in the forefront of this issue? For two reasons: one obvious, one perhaps not so obvious. Obviously electric utilities are physically out front. We are and will continue to be involved in a major way with the environment.

Our nation has been and is yet faced with an inexorable and accelerating hunger for electric energy. This hunger will not be abated or denied if we continue to be a high-energy society. Yet, there is an increasing number of responsible voices who question whether economic and industrial growth should be allowed to continue. They question whether we can have an affluent economy *and* a high-quality environment. This is the ultimate question upon which many hard social choices must be made by each of us. One hard choice: Corporations must examine the extent to which corporate responsibility to society may in some instances transcend marketing goals. This is new and uncharted territory in which I find it very difficult to predict the future.

There is a second reason for environmental discord with utilities, less obvious, perhaps. I suggest to you that in substantial measure much of the current abrasiveness between industry and environmentalists arises because public opinion has changed the rules *without prior notice*—and industry has been caught short. Less than a decade ago, the importance of environment in general was something people read about in the works of Emerson and Thoreau. It was delightful and inspirational and intellectually rewarding—but no more than that. A tree was something to cut

"There is, as I view it, one central problem at the root of the environmental concern with which all industry is struggling—the old rules of the game have changed, but the new rules are not yet developed."

down; a marsh was something to fill in. We spun a network of high-voltage lines over the countryside, and the economy bloomed. And nobody cared!

Now, there is an overwhelming consciousness about the importance of our environment, accompanied by a national guilt-complex about what we have done to it. Our affluent society has begun to worry about the price it paid to get there. It was inevitable, of course, that industry would be swept into this maelstrom, because, by common consent, industry had become a major offender of the new code, even before there was a new code.

There is, as I view it, one central problem at the root of the environmental concern with which all industry is struggling—the old rules of the game have changed, but the new rules are not yet developed. What is worse, there are, for the electric industry at least, four separate and distinct umpires refereeing the game: the ratepayer; the shareholder; the regulatory commission, or other governmental units; and the general public, which in turn is composed of several subgroups. A utility must try to serve at least four masters, each of which has a different viewpoint.

WHAT can produce workable solutions? Broader perspective is the key, together with a forum which encourages (if not requires) that perspective. This perspective must be brought to new or restructured forums—eventually, these will primarily be governmental.

What will be the nature of these new forums? That will probably be determined by time more than anything else; i.e., failure by one level of government to deal effectively with the problems in a timely way will cause them to go by default to another level. The temper of the times will not permit the problems to go unsolved. The states have in many areas defaulted responsibility to the federal government. The most recent example is water quality. States—to speak generally—would not now have water-quality standards unless encouraged and goaded by federal pursestrings. Perhaps that is a very valid role for the federal government—to goad, to persuade state problem solving.

These new governmental forums eventually must look to regional problem solving, which ignores the unrealities of political boundaries. However, I believe that a regional approach will be a long time coming. States' rights is a concept still dearly held.

Electric industry representatives often suggest that what we really need is more government, more regulation; i.e., just tell us what the rules are. While increasing regulation is probably what is going to happen (and in some areas what must happen), I don't think it is a complete solution. There is, to be sure, a compelling need for some order and for rules—both procedural and substantive—upon which industry can rely. However, a call by industry for governmental regulation—whether state or federal—must never be a substitute for individual corporate responsibility. The end result of this approach for corporations is only to place some of the real management opportunities in the hands of a political body. Please don't misunderstand these remarks to be a polemic against government regulation. *I am saying that corporations must always recognize that the letter of the law is but the beginning and not the end of corporate response.*

The law will change; it already is changing. The legal literature increasingly discusses possible bases for an "environmental lawsuit" involving some radically new concepts.

ALL of us, and I include industry, must stop the search for simplistic labels—bad guys vs. good guys, white hats vs. black hats, my side against your side. The title of this seminar implies that somehow an industrial point of view will be different from all others. A fragmented society cannot, I believe, produce bold and thoughtful solutions. The idea of compartmented groupism is deeply ingrained; our society breeds it. Yet this discontinuity and fragmentation are hostile to the new problem-solving forums which must be created. The crying need is to give prime attention to establishment of new forums which allow room for participative decision making. We must come to these forums recognizing their validity and freely surrendering the prerogative of unilateral decision making. To ignore the character of the forum is to ignore one of the major influences on final solutions.

Industry often decries the lack of perspective of others when dealing with industrial environmental problems. The long-range solution to lack of perspective must occur within the educational process itself. This means that teachers must achieve an overall perception of the problems and, more importantly, of the problem-solving process. To me, it seems to boil down to four main ingredients: much more money, both by industry and by government; more education; stronger leadership; and imaginative new ways of thinking about the problems.

There are several new ways for industry to think about environmental problems. To those industries, such as my own, which are heavily involved in environmental matters, there is one keystone proposition which must be understood and accepted. To many corporate executives, and I suspect to some educational administrators, it will sound radical.

The corporation's basic *internal* problem has been the method it has used for making environmental decisions. The problem is not peculiar to any particular industry but is a product, simply, of the way the institutional process has historically functioned. Industries make internal judgments based on *our* evaluation of economics and operational needs, though increasingly these judgments have been tempered by *our* interpretation of the public will. While that basic process is obviously valid and must continue, it has one fundamental weakness. The "public" does not have an opportunity to participate until after we have made the decision and often not until after we have passed a point of no return.

The unacceptability of "institutionalized decision making" focuses most sharply in those areas where the public feels it is most intimately involved. Thus, students and faculty feel they ought to have a larger role in university policy formation. Utility ratepayers feel they ought to be able to declare how their money should in part be spent for environmental protection. Citizens feel they have the right to judge the environmental impact caused by extraction of mineral resources. It is clear that, in the future, institutions will be less and less able to decide unilaterally what their respective publics should have. Increasingly, the corporate task will be to determine what the public wants—i.e., what the public is willing to pay for. Utility obligation will more and more involve a complete disclosure of facts, and less and less will it involve passing judgment on those facts.

This analysis produces one basic conclusion for me. Any corporate environmental program (either short- or long-range) must be built on the assumption that the corporation is willing to significantly alter the traditional decision-making process. Anything less than that is artificial and will not endure.

My own company, in an unprecedented action, announced that siting and development of all future plants and transmission lines would be discussed *in advance of decision making* with the public. We have convened virtually all environmental/conservation groups into a Citizens Advisory Task Force, together with the Governor's Environmental Cabinet, and we are talking together. Perhaps more significantly, we are listening. It is an experimental effort, to be sure, and there is no assurance it will be constructive. There is much at stake—for the community as well as for NSP. Formation of this Task Force has been noted nationally, and its progress will surely continue to be observed by all those seeking better ways of making environmental decisions.

SUCH new ways of corporate thinking can produce much in the way of new programs, some of which may be of particular interest to you. For example, the last session of the Minnesota Legislature mandated that "conservation education" shall be a part of the public school system curriculum. Unfortunately, no money was appropriated, and there the matter sits, in limbo.

My company is now examining the ways in which we might make a meaningful contribution to the environmental education process. Such examination includes helping with curriculum development and involves interrelating the physical and natural sciences with social sciences. We are looking at possible inservice teacher-training programs. We are looking at educational software. We are seeking student dialogue opportunities with environmental decision makers.

Most power companies are heavily involved in environmental monitoring programs at power plants. The monitoring programs produce more continuous and comprehensive data about the biosphere than probably is available anywhere else. What happens to those studies? They are forwarded to a regulatory agency where they are examined for compliance, and they then gather dust. What a waste! Why not try to integrate that data with appropriate laboratory and course material? Why not an honors program for outstanding science students whereby they would be employed for the summer to participate in these environmental monitoring programs? Then facilitate integration of that experience into the classroom.

Another example: Much of the lobbying for environmental/conservation legislation, at least on a state level, is done very inartfully and by inexperienced people. Too often lobbyists for this kind of legislation have little understanding of the legislative process. Most corporations lobby only for or against bills that directly affect their business interests. I would like to see corporations evaluate proposed environmental/conservation bills and in appropriate cases lobby actively for sound legislation, lending their experience and clout to the process. Such a legislative posture seems to me to be a logical extension of the social and community responsibility many corporations now exhibit in other areas.

Let me close by making one last point. Increasingly, corporations are "where the action is." In the corporate setting there are ever larger aggregations of material and human resources. It has been increasingly clear in recent times that the problems of poverty, housing, race, education will not be solved within an acceptable period unless there is substantial involvement and commitment by the private sector. This conclusion is equally true about the problems of environment. We must not lose sight of the fact that while corporations are environmental problem causers, they also are fast becoming prime problem solvers—of their own problems and also of problems totally unrelated to their economic interests. The fast emerging change in the role of some American business corporations from purely economic institutions to socio-economic-political institutions may well prove to be one of the more significant developments of the last decade.

We all are struggling to shape new criteria by which to judge corporate responsibility. Any such creative effort is always painful and halting. Speaking at least for my own company and for myself, I say we have a deep and genuine willingness to search for that consensus. What better place to start than with being willing. ☐

MAN AND HIS ENVIRONMENT:

THE ARCHITECTURAL POINT OF VIEW

Elliot L. Whitaker

OUR entire society is finally caught up in a common concern for man and his environment. By any or all standards of evaluation, the present condition of man's environment is shocking and abysmal. How, in this enlightened age of sophisticated science and advanced technology, did we arrive at this state? Individual blame is not easy to assess. We are a nation blessed with good land, an abundance of natural resources, rivers, lakes, and forests, and a favorable climate; but we have all misused our natural assets. We are all guilty of carelessness in allowing the quality of our environment to deteriorate. The question is, "What can we do to improve the quality of our environment?"

Man's environment is many faceted. It is the aggregate of all the external conditions and influences affecting his life and development. There is the natural environment of air, water, and land, contrasted with the intangible environment of man's mind, intellect, and spirit. It is this intangible environment which gives man the ability to exist in a troubled and hostile world and the ability to determine his own scale of values in deciding what is important, useful, and beautiful. Still another facet of environment, the one with which this paper deals, is the constructed environment of cities—buildings, roads, bridges, and the elements of shelter.

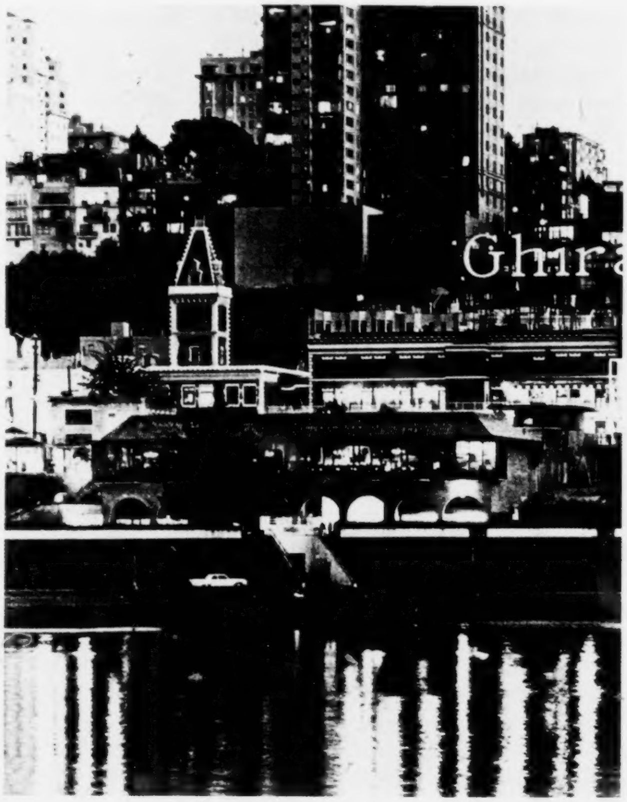
Typically, many of our major cities viewed from afar present a picture of slick, multistoried glass, steel, and concrete boxes marking the center. In many instances, only the upper stories are visible, while the lower stories swim in a sea of smoke, smog, and polluted air. Approaching the city center, one passes acres of monotonously arranged suburbs of look-alike individual houses separated from the center by billboards, strip developments of uncontrolled business, and industry. Farther in, the once elegant residences of yesteryear are evident. They no longer serve their original purpose, but rather are converted into overcrowded apartments, rooming houses, and business and commercial establishments. Interspersed are used-car lots, more billboards, an array of motels and eating establishments, each with a sign or signs more blatant than the next. The total look is one of ugliness, dreariness, vulgarity, and despair—a strange comparison with the sparkling new buildings at the center. The center may sparkle, but often it wears a daytime glitter and becomes just as dreary as its surroundings after the completion of the working day. Then the daytime occupants fight their second daily traffic battle—to return to their suburbs—leaving behind the economically and socially depressed, who are literally closeted in the slums and ghettoes of the inner city.

The author is director, School of Architecture, The Ohio State University, Columbus, Ohio, and a fellow of the American Institute of Architects. This paper was one of the NSTA-Sunoco Science Seminars presented at the annual meeting of the National Science Teachers Association, March 14, 1970, in Cincinnati, Ohio.

MAJOR cities at the turn of the century and up to 50 years ago developed and grew around a center in which, traditionally, government, business, industry, and most services were housed. One recognized this center; it was the heart of the city. Surrounding the center was housing; farther out was the rural or farming community. The arrangement was logical, convenient, and orderly. Traffic within the city was by horse-drawn vehicles and later by trolleys. Communication between cities was by rail or boat. The motor age and the population explosion were yet to come.

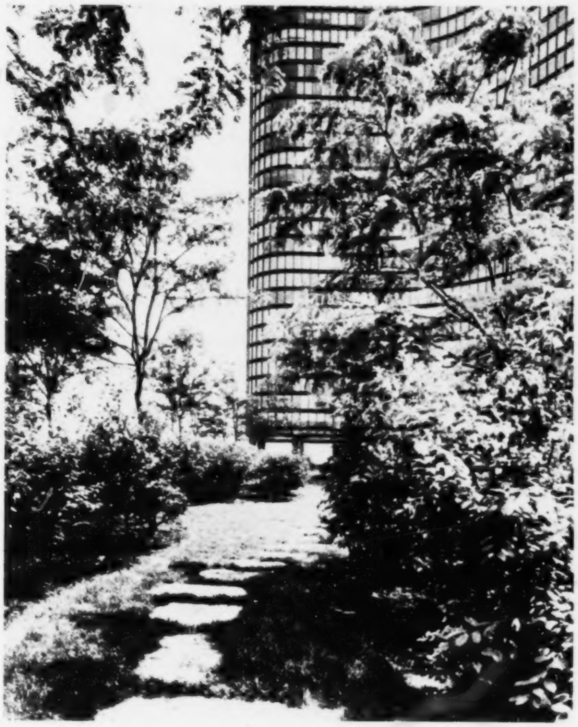
Today, our cities and cars are on a collision course. Annually, more people are killed or injured by auto accidents than by all recorded wars. Choked roads are replaced by choked concrete superhighways which snake and finally bludgeon their way into the heart of every city. Americans have become mobile, and the new mobility has resulted in unbelievable sprawl, strip developments, and the despoliation of roadside and recreation areas. The urbanized areas of the East Coast of the United States (extending from Portland, Maine, south through Boston, New York, New Jersey, to Baltimore and Washington) are considered one huge, sprawling, continuous city, often referred to as Megalopolis. The same conditions exist in parts of the Midwest and along the West Coast. One might imagine that poor planning, jammed highways, overcrowding, dirt, noise, and ugliness could only serve as a warning to newer cities and that the same mistakes would not be made again. Unfortunately, this is not the case. There is a strange similarity in cities, and all in one way or another seem to share the same problems.

WE might ask at this juncture whether cities are doomed. Is there really any hope of solving the complex problems of urban living? Archaeologists have discovered traces of ancient cities in unrelated corners of the world which, for reasons yet unknown, the inhabitants abandoned. We do not have that alternative; what then can we do? Already, strong public opposition to certain new freeway



The old and the new can contribute to the revitalization of our cities. Above: The Cannery (left) and Ghirardelli Square (right) are imaginative San Francisco examples of old manufacturing facilities which have been turned into attractive shopping centers. Below: Lake Point Tower (left), a very large high-rise apartment building in Chicago, Illinois, and Greenbriar Shopping Center in Atlanta, Georgia, represent the exciting contributions that modern architecture can make to the appearance of a city.

AMERICAN INSTITUTE OF ARCHITECTS



construction in several cities, including Boston, Staten Island, Baltimore, New Orleans, and San Francisco, has effectively halted the building of superhighways, which were proven to be disruptive to existing good patterns of urban living. Most of these actions delayed the new flow of auto traffic only temporarily. However, in Baltimore, through constructive alternative proposals of an interdisciplinary team of architects, engineers, planners, and sociologists, the once halted superhighway is now going ahead. But it is proceeding in more favorable locations and using new design concepts which allow both the highways and the neighborhoods to benefit. The superhighway as characterized by the best of the Interstate System and parkways and roads to recreation areas are excellent examples of good design and preservation of natural resources. By employing new, imaginative, interdisciplinary solutions, the superhighway can also be a major element of good city design.

Major cities throughout the United States are discovering new excitement and new economic gains in revitalizing the downtown areas. New architecture, open spaces, separation of pedestrian and vehicular traffic, the return of nature—trees, plants, grass, flowers, and water—attract people and bring money back to the city. The list of these cities is long and impressive. It includes Boston, New York, Baltimore, Pittsburgh, Philadelphia, Atlanta, Columbus, Indianapolis, St. Louis, Kansas City, Dallas, San Antonio, Seattle, and San Francisco. In Cincinnati, where the National Science Teachers Association met in March, annual meeting participants had an excellent opportunity to witness a city in transition. The story of the Fountain Square Project in downtown Cincinnati, now nearing completion, dates back to 1963. It is worth a visit.

Concurrently with the revitalizing process, cities have also learned the lesson of preserving the best of our past in architecture, landscape architecture, and planning. These preserved areas, protected against encroachment, are returning new taxes to the city coffers. Notable among many examples are Boston's Beacon Hill, New York's Rockefeller Center, Philadelphia's Society Hill, Washington's Georgetown, Colonial Williamsburg in Virginia, San Antonio's River Project, San Francisco's Cannery and Ghirardelli Square, and Columbus's German Village.

ALTHOUGH some recent gains have been made in housing through slum clearance, the Model Cities Program, public housing, and private enterprise, the total picture is not good. A rapid rise in urban population, deterioration of existing housing, high interest rates, inadequate new land for development, skyrocketing construction costs, antiquated construction practices, outdated building codes all add up to a dismal outlook. Replacement of deteriorated and obsolete housing alone is a staggering task. Some neighborhoods can and are being saved; some new neighborhoods are under construction, but it will take a dedication equal to the efforts which set our astronauts on the moon if the United States is to solve its housing problems by the end of this century.

It is estimated that in the next 30 years this nation must build as much housing as it has in the past 350. This means we must build the equivalent of one new city the size of Toledo every month from now to the end of the century, just to keep pace with population growth.

John W. Gardner, chairman of the Urban Coalition and former Secretary of the Department of Health, Education, and Welfare, in a paper presented to the 1969 Panel on Science and Technology and the Cities, of the Committee on Science and Astronautics, U.S. House of Representatives, claimed that housing is our most urgent problem. He said that federal assistance at all levels, new concepts of construction, new and innovative uses of labor—in fact, the entire spectrum of support by the entire economy—are needed if we are to succeed in meeting housing needs.

Athelstan Spilhaus, former president of the Franklin Institute of Science in Philadelphia, reported in a paper given to the same panel:

> Cities have always been the centers of learning whether in formal institutions or merely by the experience of living in them. When we talk about building a city, we think too much of the housing and often too little of the services to people. In the United States, for example, we are preoccupied with rebuilding ghettos, yet the houses we tear down are far, far better than those that the bulk of the world's population live in. Countries vary in their material resources and in the degree of development of these resources . . . every country has human resources in excess of our ability to use them fully. Therefore, *we should concentrate on people services* in the new culture, recognizing that we are all in the service of others, without servility. The new culture should value human services to human beings more highly than the shelters for living.
>
> I dream of a city where the dwelling units are simple and adequate but the services in education, sanitation, health, recreation, art, music, and all forms of culture are magnificent. In my proposal for the experimental city . . . essential people-services will be preplanned for the number of people the city is to contain. Entirely new technologies—pollutionless factories; noiseless, fumeless transportation; reuse of waste; and a complete information utility would be planned. Buildings will be demountable as rapid technological and social change makes them obsolete. Even community structures should be completely flexible as the uses and needs of the community develop.[1]

One of the most promising and exciting possibilities for the improvement of man's environment is in the development of "new towns" described above by Dr. Spilhaus. Already in Europe the new towns of Tapiola, Finland; Vallingby, Sweden; and Cumbernauld, England, are completed examples worthy of careful study and emulation. In this country, Reston, Virginia, and Columbia, Maryland, now under construction, are the first American "new towns."

The "new town" concept provides for an orderly, planned development of total new communities. These communities are not considered substitutes for cities, but are planned in addition to existing cities. The characteristics of a "new town" include a full range and choice of housing and job opportunities and commercial, industrial, community, cultural, transportation, and educational opportunities. Ideally, the total environment will include the environmental enhancements described by Dr. Spilhaus.

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[1] See also Athelstan Spilhaus, "Why Have Cities?" *TST* 36:16-18; December 1969.

Max Ways, in the February 1970 issue of *Fortune* magazine, says:

> The chief product of the future society is destined to be not food, not things, but the quality of the society itself. High on the list of what we mean by quality stand the questions of how we deal with the material world, related as that is to how we deal with one another. That we have the wealth and the power to achieve a better environment is sure. That we have the wisdom and charity to do so remains—and must always remain—uncertain.[2]

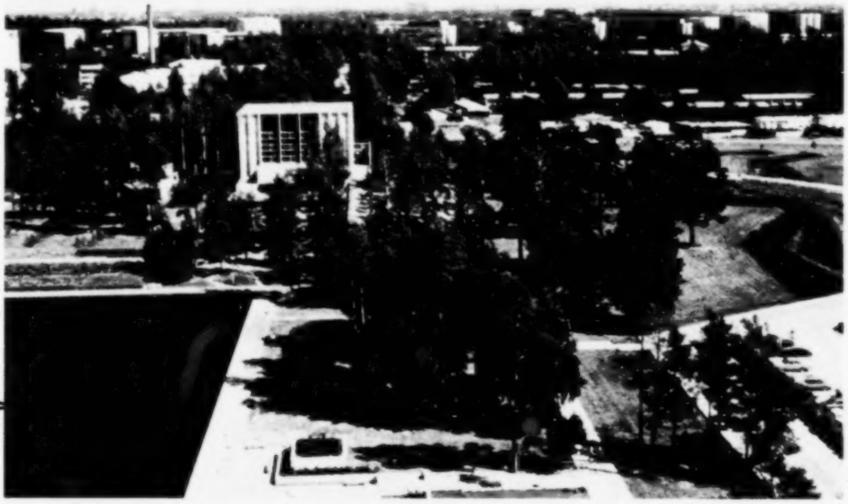
Alfred B. Garrett, ~~retiring~~ president of NSTA, asserts, "Science education must 'gear up' to meet the challenge of . . . the most critical century that civilization has ever faced." In accepting this charge, the science teacher must also accept the responsibility of sharpening his own knowledge about the environmental problems of the planet on which we live and the people who inhabit it. Then, in turn, he must share this new knowledge with his students.

Today's students will not wait for a new century. They are anxious, frustrated, and personally concerned. They seek immediate and relevant solutions to the real-life, environmental problems of today!

Understandably, there is no ready-made environmental cure-all; but certainly, by the effective use of known scientific methods applied to science teaching, the science teacher can help in the search for answers to the qualitative improvement of man's physical environment. Out of this action could possibly develop new scientific approaches to the entire range of environmental problems, even to a new science of the control of man's physical environment.

A better future is indeed within our grasp, how does the science teacher propose to respond to the challenge?

To repeat President Nixon's words in the environmental issue of *Fortune* magazine for February 1970, "If we are to materially improve our environment . . . then *all* of our people must join in that effort." ☐



One of Europe's new towns, Tapiola, Finland.

Reston, Virginia, is a 7,400-acre development 18 miles west of Washington, D.C. Its present population is 8,000, but this is projected eventually to reach more than 75,000. The project uses mixed zoning laws to integrate low-, medium-, and high-density residential communities with shops and commercial facilities. Over 1,000 acres are set aside for government and industry. Recreational facilities and permanent open space are included in the master plan.

COURTESY, AMERICAN INSTITUTE OF ARCHITECTS

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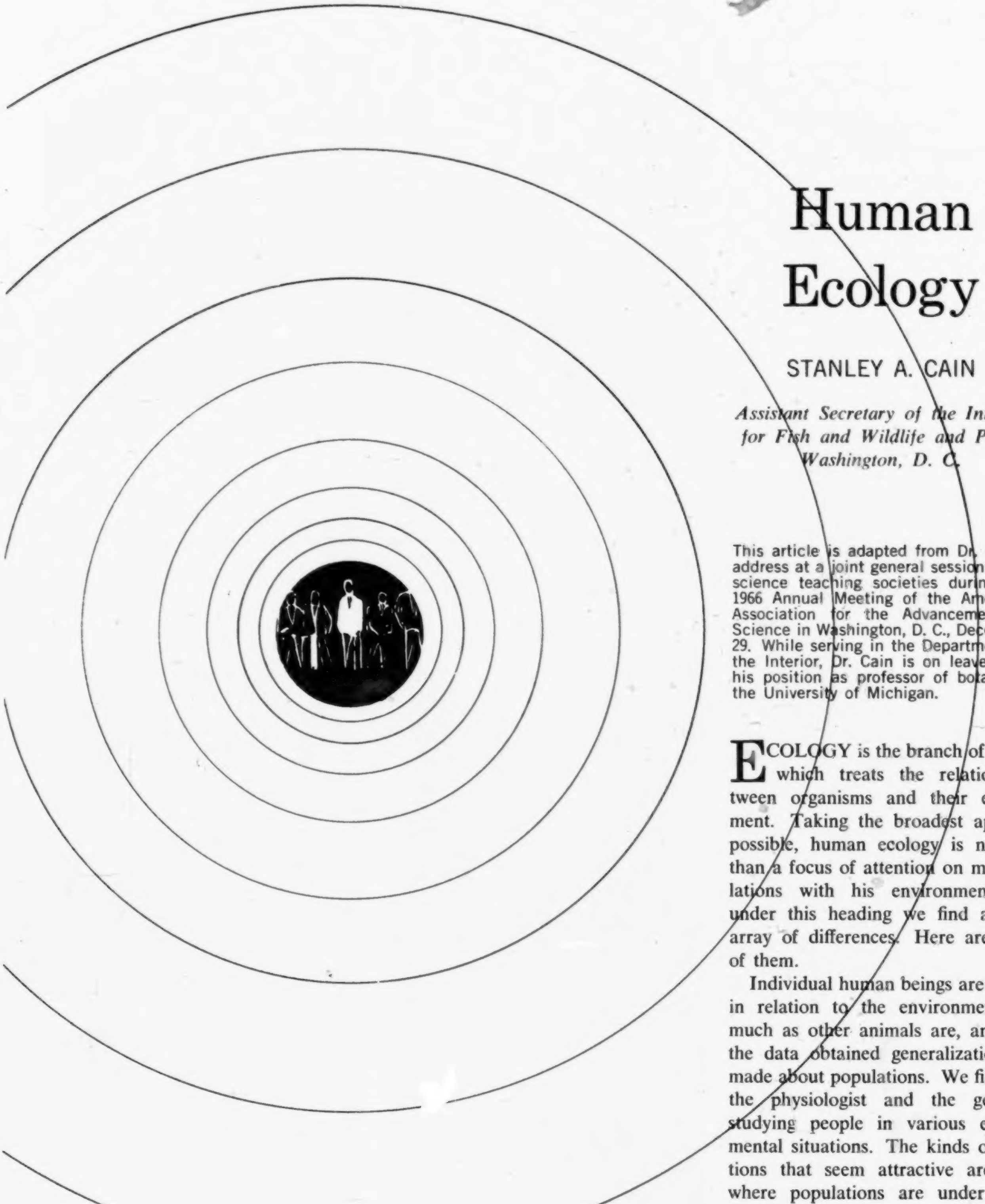
[2] Ways, Max. "How to Think About the Environment." *Fortune* 81:166; February 1970.



Human Ecology

STANLEY A. CAIN

Assistant Secretary of the Interior for Fish and Wildlife and Parks Washington, D. C.

This article is adapted from Dr. Cain's address at a joint general session of all science teaching societies during the 1966 Annual Meeting of the American Association for the Advancement of Science in Washington, D. C., December 29. While serving in the Department of the Interior, Dr. Cain is on leave from his position as professor of botany at the University of Michigan.

ECOLOGY is the branch of biology which treats the relations between organisms and their environment. Taking the broadest approach possible, human ecology is no more than a focus of attention on man's relations with his environment. But under this heading we find a broad array of differences. Here are a few of them.

Individual human beings are studied in relation to the environment very much as other animals are, and from the data obtained generalizations are made about populations. We find both the physiologist and the geneticist studying people in various environmental situations. The kinds of situations that seem attractive are those where populations are under stress, such as heat and cold stress, water stress, high-altitude stress, or where groups of individuals are under activity stress, such as athletic stress or the stresses of certain occupations.

This approach to human ecology is well illustrated by the UNESCO "Arid Zone Research Report VIII, Human and Animal Ecology." Under Human Ecology, the contributors were asked to cover the following aspects:

1. The influence of environment on human communities in arid regions and the adaptation of such communities to conditions existing in those regions, with special reference to housing, clothing, food, and other social conditions, and comparing (a) stationary and nomadic peoples, and (b) long established with recently immigrant communities.
2. The influence of environment in arid regions on the anatomy, physiology, biochemistry, and pathology of human beings, to include the adaptation of local and immigrant populations to this environment.

In response to this directive, W. S. S. Ladell, Director of the Hot Climate Physiological Research Unit, Oshodi, Nigeria, treated the subject of human ecology in the typical autecological-physiological manner, as shown by the following topics taken up in his review:

- Heat regulation
  - Body temperature and thermal equilibrium
  - Heat loss
- The skin
  - Skin temperature
  - Insensible water loss
  - Sweat secretion
  - Composition of sweat
- Circulation of heat
- Water metabolism
  - Fluid and electrolyte changes
- The endrocrines in heat
- Heat tolerance
  - Acclimatization to heat
  - Tolerance to heat
  - Air movement
  - Limiting environments
- Modifying factors in heat tolerance
  - Clothing and housing
  - Radiation
  - Nutrition
- Mental effects of heat
- Desert thirst
- Pathology of the desert
  - Effects of solar radiation
  - Prickly heat
  - Testicular changes
  - Tropical fatigue
  - Salt deficiency dehydration
  - Anhidrotic heat asthenia (lack of strength)
  - Heat stroke
- Racial differences
  - Metabolic rate and heat production
  - Skin color
  - Blood
- Anatomical differences

In this contribution there is not much attention given to part of what UNESCO was interested in: housing, clothing, food, and other social conditions, or to comparing stationary and nomadic and long-established and immigrant communities—that branch of ecology (to refer to another dictionary definition) of the sociologists concerned with the spacing of people and of institutions and their resulting interdependency.

Emphasizing this latter aspect of human ecology, another paper in the UNESCO report is by Regina Rochefort, who says:

> Few arid regions today are left untouched by modern civilization. In the place of traditional adaptation to local environmental possibilities to ensure the livelihood of the group, powerful techniques are now employed to transform the natural conditions and to bring these countries and their inhabitants within the orbit of modern civilization. However, these new techniques for agricultural development or for the production of new sources of wealth through the exploitation of the sub-soil are often introduced purely for speculative purposes, the aim being to derive immediate profit from these plants set up by private companies. The new ways of exploiting the environment may thus have harmful effect on the development of the arid regions either because they seriously jeopardize the natural equilibrium (by exhausting water supplies or through soil erosion), or because they bring about a crisis and impoverishment of the traditional communities, riding roughshod over them.

In the primitive case, the human ecology is based on close adaptation to environmental conditions, including such institutionalized practices that make for adaptation and that assure its maintenance. In the other case, the intruding actions of institutions of industry and finance include the application, in the desert environment, of things and conditions characteristic of temperate-zone developed countries, including import of water and power, food and machinery, and the negating of the natural environment by air-conditioned housing and other devices for comfort.

ECOLOGY is a science that has its analytic aspects; but its essence is integrative. Its principal business is synthesis because it tends to deal with dynamic complexes that subsume the various systems which occupy the attention of the specializations of the natural and social sciences. Hence one finds a growing interest in human ecology in the fields of medicine and public health—mental health, environmental health, epidemiology, pathology, and the like.

With the growing pressures of exploding human populations and the consequent need to intensify production and the productivity of human effort—especially, but not by any means exclusively, in developing countries—there is more attention being given to whole economies and to relationships between economics and ecology. Slowly there is arising the realization that uncoordinated scientific, technological, fiscal, political, social, and other attempts at change are failing to accomplish the needed adjustment between human needs and their fulfillment. This change is showing up in UNESCO, WHO, FAO, in the various international banks, in AID, and other bilateral and multilateral programs of assistance. Even at home, state and federal agencies are seeking devices for coordination of effort.

To the extent that we are shifting toward a concern for interactions and inter-relations in what we do, we are moving in the direction of ecological thinking. As we do this, however, we are discovering a relative dearth of information and understanding because our attention has been on other matters. This gap will not be filled readily because of the complexity of the inter-relations and also because our successes in the areas where quantification is a god and prediction is secure, leave many scientists and engineers uncomfortable and sometimes unwilling to forsake the security of their familiar technical niches.

This problem is clear in the field of conservation where society can no longer afford the uncoordinated development and use of natural resources, the consequence of which has been an accelerating deterioration of the quality of our environment. It is this growing ecological awareness that is producing public concern with all forms of pollution, loss of open space, natural areas, and natural beauty.

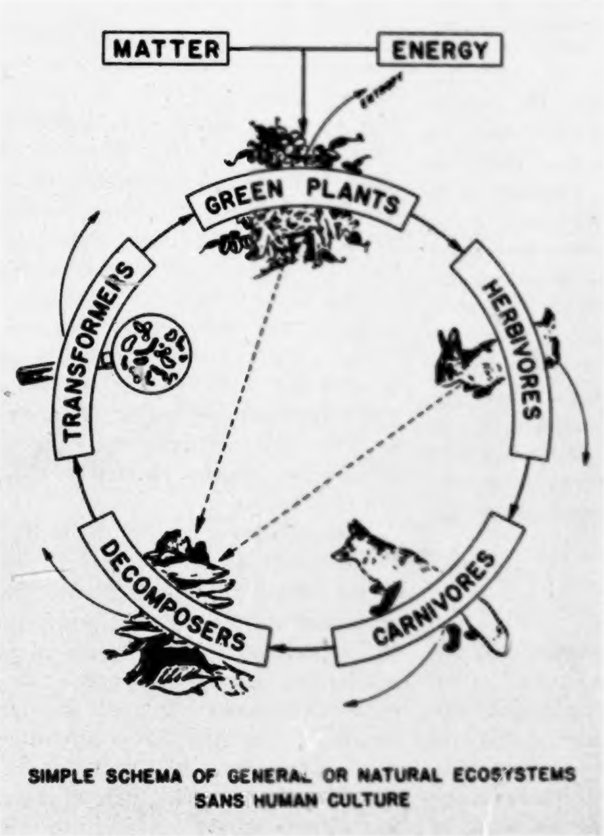
THE first phases of conservation were corrective—the early and weak efforts to apply ecological thinking to stopping the processes that were deteriorative of the human environment and that were reducing man's productivity of goods and services. This might be dubbed the study of "inhuman ecology" and the taking of efforts to humanize man's activities.

If, however, we look closely at the basic ecological problem, we find that there is a fundamental similarity for all life. Any organism, if it is to stay alive, must solve the problem of acquisition, transformation, use, and disposal of matter and energy. The working out of this problem is a matter of interrelations between living units and their environments. There is, then, an intracellular, perhaps molecular ecology, as well as the complicated relationships within the organism among its tissues and organs and the substances and conditions they produce. There is also the familiar ecology of the organism as a whole in relation to its constantly changing environment and a different ecology of monospecific populations, and of plant-animal communities.

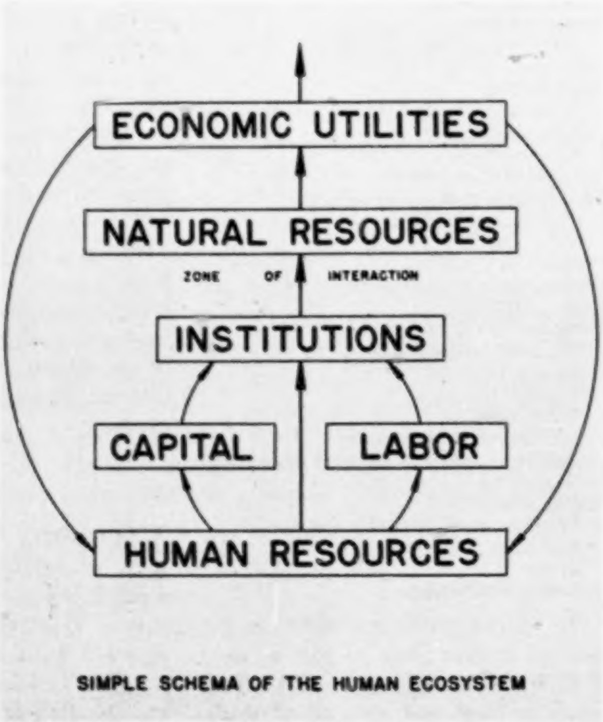
This array of relationships is the ecology that man shares with all other organisms. Human ecology in this sense differs little if at all from general ecology, even at the community level where human effects on the ecosystems are negligible or ignored in studies of terrestrial and aquatic situations—forests, grasslands, hot and cold deserts, lakes, streams, and oceans.

WHEN the focus of attention is on man, we find that in most situations he has become a predominant influent in nature. In going about his biological business, that is, in attempting to solve his fundamental problem of the acquisition of needed matter and energy, he has been remodeling the natural world and bending it to his will. If there is any growing revulsion to this, it is not because of his intentions but because of his mistakes. Even the extreme preservationist, who is a defender of *nature qua nature* and would grant any species an implicit right to existence, is generally concerned with nature in relation to man—its interest, its beauty, and its relation to his own personality.

But there is little present sense in viewing human ecology in any other reference than to contemporary industrial society, with the expression "industrial society" encompassing the entire gamut from the Neolithic to the contemporary. Industrialization is a matter of how man obtains from the environment what he needs in the way of matter and energy. I would like to turn, then, to a general model of the human ecosystem which treats the same problem as the usual models of



SIMPLE SCHEMA OF GENERAL OR NATURAL ECOSYSTEMS SANS HUMAN CULTURE



SIMPLE SCHEMA OF THE HUMAN ECOSYSTEM

natural ecosystems, but does so in a strikingly different way.

The simple form of this schema of the generalized human ecosystem says that man's contacts with nature occur in the social context. In a diagram, one sees that the economic utilities that support both the individual and the human community are wrested from natural resources by man's institutionalized application of his labor and capital. Contemporary man carries on scarcely any productive activity alone. It is clear that the wresting of raw materials from nature and the use of nature's products and processes is accomplished by concerted human effort. To accomplish this concerted effort, man has created a great many institutions related to agriculture, forestry, fishing, mining, and so on, as well as to business, financial, industrial, commercial, and social endeavors.

The human ecosystem, however, is involved in the production of much more than goods. In this connection we readily recognize the institutions of the family and larger social groups as well as those related to religion, education, politics, law, security, the creative arts, communication, and the use of leisure time. In fact, there is almost nothing that modern man does that is without some institutionalized aspect.

This usage of the term "institution" to cover any established cooperative effort is broad but fully warranted. In addition to an organization or establishment for the promotion of a particular objective, and a concern engaged in some commercial activity, the term properly includes any organized pattern of group behavior, well-established and accepted as a fundamental part of culture, and any established law or custom.

THE simple model of the human ecosystem that I have proposed uses the economic concepts of labor, capital, land, and economic utilities in a flow scheme that gives institutions a central role and which, as a system, is capable of homeostasis and evolution.

In this schema, labor is conceived to include all of man's personal means of production. This implies correctly that the human ecosystem is a production system just as truly as does any model of general ecosystems. Under "labor" we would include the total human population of a given ecosystem as well as the labor force which is that portion productively engaged at any period of time. It is not enough, however, to know how many persons are involved or how large the labor force may be. To evaluate this aspect of the functioning of a human ecosystem, we need to know what skills the labor force has and the relative abundance of each one. Besides knowledge and skills, the personal means of production are influenced by health, understanding, concepts, aspirations, and the impinging influences of other segments of the ecosystem.

Capital in this schema has no direct relationship to money and land or the ownership of natural resources. By "capital" is meant all of the physical means of production that man has created. Here, then, are the tools, implements, weapons, machines, and physical facilities that man has invented, built, and employed in the production process.

The flow of labor and capital through institutions in the production process means that all contemporary human productive effort is socialized. Institutions, like the tools of capital, are human inventions: in their case, for the cooperative use of the productive capacity of labor in wresting goods and services from nature.

The economists' ancient concept of "land" is here required to include the total environment that contains the natural resources; that is, the things, conditions, and processes in nature that man can utilize in his life processes, both biological and cultural.

At this point we must emphasize the difference between human and general ecosystems. I have already stressed the biological identity that resides in the need for matter and energy that characterizes all life—to sustain the organism and to allow it to grow, develop, and reproduce. Man, not being a primary producer, participates like all animals in the food web through which minerals cycle and energy flows. But man, very differently from other animals, has created a fantastic demand for external, nonphysiologic, matter and energy. This includes all of the materials that are used in clothing, housing, and other constructions, and the external energy resources that provide environment control, such as heating and cooling and humidity regulation, and that power his machines and instruments.

Although there is some control of environment by animals, such as nest- and den-building, slight use of tools, such as picks and stones, by a few vertebrates, and some rudiments of noninstinctual socialization in the collective action of family groups, such as hunting packs of wolves, there is not really a shadow of things to come in any animal group other than the early hominoid primates. Human ecosystems, then, must be studied entirely differently if we are to grasp the differences rather than get stranded on studies of biological similarities.

Human ecosystems are capable of attaining a state of homeostasis or self-regulation. The products of the functioning system are used to sustain the system. In the simplest of biological terms, food produced as an economic utility is employed to nourish the labor that produced it, and the materials that are produced are used to develop and replenish the capital that labor uses in the production process. Thus the interaction between the human resources and the natural resources—that is, between labor, capital, and institutions on one hand and land on the other—in a given human ecosystem can maintain that system as long as the system is viable and the supply of natural resources is not exhausted.

The final and very important point to this simple but fundamental concept of the human ecosystem is that it is capable of growth, development, and evolution. If the functioning system produces an excess over that necessary to maintain it, and if the surplus is productively invested, the system can grow and develop. In the simplest terms, this means that the population can grow. In a more meaningful sense, it means that the population can be improved as to its socioeconomic conditions. For example, a surplus input to the labor sector can result in an improvement in the institutions of educational and social, political, and economic organization so that the productivity of labor is increased. A more skillful, better tooled labor force can increase its rate of production and, consequently, its wealth—production being the only operational source of wealth. Similarly, on the physical side, the feedback of surplus production can mean improvement of the physical and institutional means of production.

HUMAN ecology, when it becomes more than the autecology of man living under stressful environmental conditions, gets involved in that fascinating nest of problems that includes ethology, comparative psychology, and social structure. Having suggested a simple but general model of the human ecosystem, I have hoped that it will serve certain purposes. If it is sound, it should:

1. Aid the organization of existing knowledge and extend the range and implication of hypotheses
2. Help guide research and the formulation of new hypotheses
3. Help overcome some of the biases and inadequacies that flow from compartmentalization of knowledge in the processes of education, research, and technological application
4. Help in the design, regulation, and improvement of human ecosystems, i.e., help in the conservation management of human environmental inter-relations

Our considerable present interest in putting ecology to work for human betterment should be accompanied by serious but cautious efforts to manipulate human ecosystems. At the same time, because man has invented both his capital of tools and the institutions by means of which his ecological system works, he can no longer safely approach nature in terms of natural resources as though they were discrete and isolated one from another. I find it hopeful that some countries are extending ecological knowledge and practices to the landscape, as distinct from the familiar product orientation, in both urban and rural land-use planning. The key to these changes, slight though they may be, is to be found in what in the first instance may be little more than slogans, such as "quality of the environment," "pollution abatement," "natural beauty," "maintenance of human scale," and "integrated resource development and use."

Among the necessary conditions for satisfactory relationships between man and environment are knowledge of the physical environment, of man's living associates, and of the relationships among them. But this is not enough. Man is more than an animal. His ecology must encompass also what man himself creates.

MY MODEL of the human ecosystem, simple but capable of endless elaboration, is essentially a theory of human action. The social aspect of this lies in the properties of the system of interaction of human groups *vis-à-vis* the institutions through which they act. The orientation is that of the individual, the actor in the action system, but an institution exists because there is a "collectivity of actors," as Talcott Parsons and Edward Shils state it in their book, *Toward a General Theory of Action.* In a strict sense, the concept of motivation applies to the individual, but in the organized systems of institutions, there is motivational component in the concerted action of a group when it is guided by the meaning which a human attaches to the institution in relationship to his own goals and interests. Furthermore, within this action system, the scope for choice rests on "standards which may be either cognitive standards of truthfulness, appreciative standards of appropriateness, or moral standards of rightness." Finally, when relationships between human groups and institutions have become the norm, an individual cannot violate the cognitive, appropriate, and moral standards without a feeling of guilt.

This line of reasoning leads me to the conclusion that planned change in human ecosystems will not succeed until the cultural pattern has been internalized and sufficient individuals want to conform to the cultural pattern and show guilt and distress when they do not. Many felt needs lie between the individual's physiological needs for food, shelter, family, and security and the environment and its natural resources and natural resistances. But in any case, the individual first selects a cultural vehicle for the satisfaction of his felt needs, and ends up by being committed to it. This would seem to be both the explanation of the formation of human ecosystems and a hint as to how their change may be guided. The institutions, which form such an important part of the human ecosystem, are not easily changed, because with time they develop their own quasi-organismal characteristics and reason for being. Many an institution that has outlived its rational basis continues for decades, even centuries, because of the vested interest in it. Examples are everywhere. I will mention by way of illustration the institutions of slavery, royalty, latifundia, the penal treatment of poverty or alcoholism, and the anachronistic continuation of single-purpose business or governmental practices and agencies after their functions have exhausted their rational basis.

My intention is not to end on a pessimistic note, nor to have discouraged any branch of research on human ecology, but to say that more attention needs to be directed toward understanding human ecosystems as comprehensively as possible with the ultimate goal of managing them insofar as may be feasible for the humanistic as well as for the materialistic benefit of mankind. ##

Peter A. Breysse

SOUND POLLUTION—ANOTHER URBAN PROBLEM

IN A RECENT article entitled "Noise and Urban Man," Robert Alex Baron states:

> Noise abatement and the need for it are virtually neglected issues in American life today. Unless the medical and public health professions become deeply involved in these problems, it is likely that apathy and inertia will defer any effective action for another decade or even longer. But we, the public, cannot wait that long. Air pollution kills us slowly but silently; noise makes each day a torment.[1]

Noise, defined as "unwanted sound," surrounds today's urban dweller in an excessive and gradually increasing diet of decibels. While it is generally accepted that noise is unwanted sound, there is no universally agreed-upon definition for sound pollution. Sound pollution may be defined as the presence in the environment of noise resulting from human activities, which is of sufficient quantity and quality to adversely affect man's well-being, either physiologically or psychologically and/or interfere with man's full use and enjoyment of his property.

To fully appreciate the complexity of the sound pollution problem, we may need to review briefly this phenomenon called sound. Sound consists of a series of vibrations in an elastic medium. A vibrating body, such as a guitar string, produces compression waves. As these waves emanate from the vibrating body, molecules of the transmitting medium—air, for example—are alternately compressed and expanded (Figure 1). Thus, sound is transmitted through compressible matter. Sound waves generally travel faster in dense materials. The velocity of sound in air is 1,130 feet per second (ft/sec); in water, 4,500 ft/sec; and in steel, 15,000 ft/sec.

When sound is transmitted through the atmosphere, the vibrations may impinge upon the human ear which, if functioning properly, transmits the physical energy to the auditory nerves. The normal ear distinguishes between sounds by detecting the different tones of which each sound is composed. The audible tones (Figure 2) range from approximately 16 Hertz (HZ) to 16,000 HZ (HZ = cycles per second). The principal speech range extends from approximately 300 to 3,500 HZ. At the lower and upper ends of the spectrum, higher energies are necessary to discern these sounds. Below 16 HZ we are in the region of vibrations, and above 20,000 HZ in the ultrasonic region. The threshold of discomfort begins at 120 decibels (db) and the threshold of pain at 130 db.

The characteristic sounds of the urban environment consist of pure tones (sound of single frequency) and random sounds (those with no consistent tone, such as a waterfall). This combination of pure tones and random sounds forms what are called complex sounds.

The human ear is an amazing instrument. It can recognize and classify approximately 340,000 separate tones,

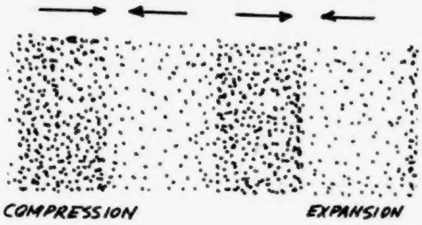


Figure 1. Alternate compression and expansion of molecules of the transmitting medium creates sound waves.

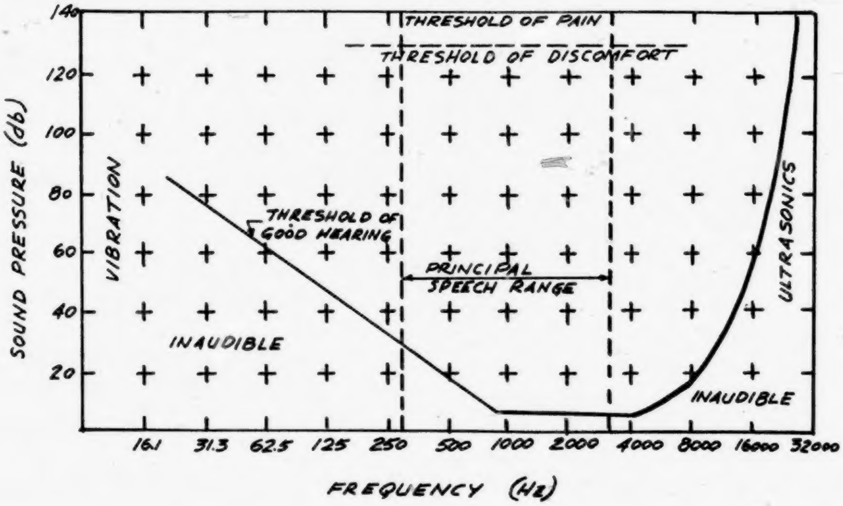


Figure 2. The auditory field of humans ranges from approximately 16 to 16,000 cycles per second.

Mr. Breysse is a research assistant professor in the Environmental Health Division of the University of Washington, Seattle. This paper is adapted from his talk on the same topic at the 1969 NSTA regional conference in Seattle on October 18.

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[1] Baron, Robert Alex. "Noise and Urban Man." *American Journal of Public Health* 58: 2060-2066; November 1968.

and it can hear without damage a sound pressure 10 million times greater than the sound pressure of the softest intelligible sound. Because of this wide range of responses, a system of logarithms is utilized to measure sound intensity. Originally, sound intensity was defined in terms of sound power. Because sound power cannot be measured directly and sound pressure can, power was converted to pressure such that:

$$\text{Sound Pressure Level (db) (SPL)} = 20 \log_{10} \frac{\text{Measured Pressure}}{\text{Reference Pressure}}$$

Reference Pressure
= 0.0002 (dynes/cm^2)

Source	*SPL (db)*
Jet plane (100 ft)	140
Riveter	120
Rock and roll music	120
Cub Scout meeting (at times)	110
Subway train (inside)	95-110
Automobile (inside—window open)	95-110
City traffic	90-110
Normal conversation	60-70
Quiet office	40-60
Whisper	40-60
Threshold of hearing	0[a]

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[a] This differs for individuals.

Since SPL is based on a logarithmic relationship, intensities of multiple sources cannot be added arithmetically. The additive effect of two SPLs of the same magnitude would theoretically increase the SPL 6 db, provided that the two sounds are exactly in phase. If, on the other hand, the sounds are not in phase, then the overall SPL would be increased 3 db—thus 90 db + 90 db = 93 db.

INSTRUMENTS for measuring sound are called sound-level meters and analyzers. The sound-level meter consists of a microphone, an amplifier, and an indicator. The meters respond to frequencies between 20 to 20,000 HZ. Current instruments are designed to meet specifications established by the United States of America Standards Institute (USASI). Most sound-level meters are equipped with three elec-

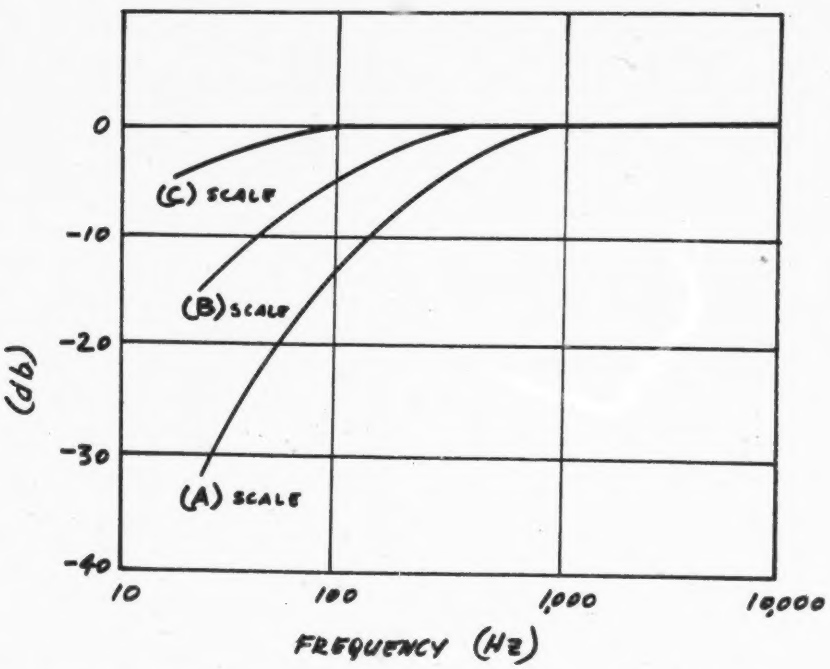

Figure 3. Weighting characteristics for sound-pressure-level measurements. Most sound-level meters are equipped with three electrical weighting or filter networks (A, B, and C), which enable the instrument to approximate the response of the ear at different sound-pressure levels.

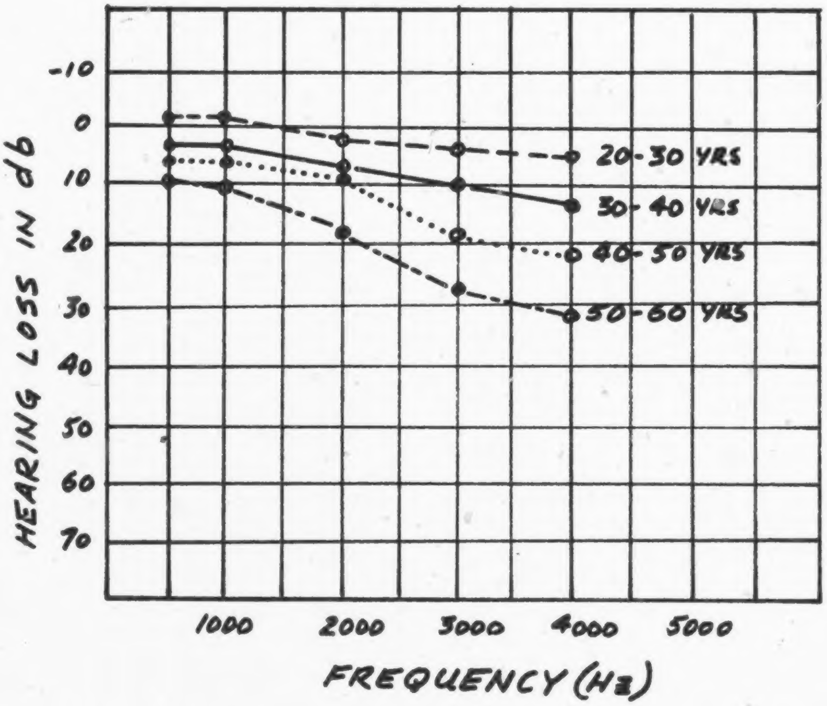

Figure 4. Results of five studies involving hearing loss with age in men.

trical weighting or filter networks A, B, and C, which enable the instrument to approximate the response of the ear at sound-pressure levels about 40, 70, and 100 db. Figure 3 represents the approximate weighting characteristics for the A, B, and C networks.

Because the various networks cut out certain portions of the lower frequencies, it is important that the network utilized for obtaining an SPL measurement be part of the designation for that measurement—for example, 78 dbA, 78 dbB, or 78 dbC. If the network is not shown, then it must be assumed that the measurement was made utilizing the "C" scale. This network aspect can be confusing, since a noise source may have sound-pressure-level readings of 75 dbA and 95 dbC, while another source may have readings of 75 dbA and 80 dbC. If we compare these two sources by their "A" scale readings, it might be assumed that they are of equal intensities. On the other hand, their "C" scale readings are quite different.[1] It is, therefore, important that these facts be kept in mind when attempting to compare intensities of different sources.

A number of sound-measuring meters also contain frequency analyzers, which are capable of determining intensities with discrete frequency ranges. The most common type of frequency-band analyzer permits analysis of frequency bands one octave in width.

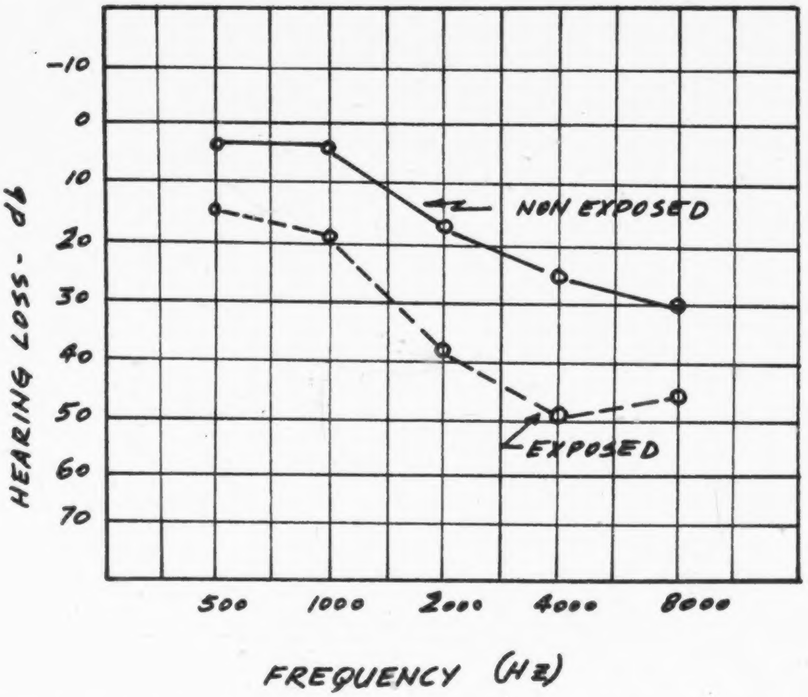

Figure 5. Hearing losses by a group exposed to industrial noise (90-100 db) for an average period of 26 years exceeded those by a nonexposed group.

EXCESSIVE exposure of humans to noise can produce both physical and psychological manifestations. The initial symptoms of noise exposure below the threshold of pain are usually discomfort, headache, and temporary hearing loss. If the exposure is allowed to continue over a period of years, gradual permanent hearing impairment may develop. During the youthful years—up to 30—noise-induced damage is rarely permanent, with the effects being sufficiently mild to be reversible.

Other physiological effects besides hearing impairment have been reported. Certain noises may produce alterations in respiration, circulation, basal metabolic rate, and muscle tension. Workers exposed to noise have complained of irritability and sleeping disturbances. Reactions may be manifested by nausea, vomiting, and disturbances of equilibrium. Noise-exposed workers have also been subject to chronic gastritis. Increases in peripheral vascular resistance and decreases in arterial blood flow along with diminution in salivary gland and gastric secretions may also result. Foreign studies have reported an increased incidence of cardiovascular ailments in workmen routinely exposed to high levels of industrial noise. In some cases, a fatal effect has been ascribed to highly intense jet plane noise.

Equally as important and very likely more important than the physical effects are the possible psychological effects. Psychological reactions, similar to physical responses, involve a multiplicity of factors which vary with the characteristics of the sound—its intensity, frequency, intermittency—as well as the inappropriateness of the stimulus, interference with speech communications, and the unexpectedness of the noise. The type of noise, rather than the intensity, is usually the deciding factor in influencing emotional reactions. A sudden scream, a grating piece of chalk, and a dripping faucet—all involve different yet characteristic emotional responses. Unfortunately, our knowledge has not yet reached the point where the complaint threshold associated with a given noise stimulus can be predicted with any degree of reliability; the variations of human reponses are simply too great. Furthermore, we are totally ignorant of the overall long-term effects to our physical and psychological well-being from these continued annoyances.

HUMANS develop hearing loss with aging. Figure 4 is a summary of five studies involving hearing loss with age in men. In the past the gradual degradation of the hearing ability of the general population was thought to be strictly due to the aging process. A hearing study conducted among one African tribe indicates that the tribal elders suffered much less hearing loss than did their modern urban contemporaries. These tribesmen lived in an atmosphere of virtual silence. On the other hand, a similar investigation was conducted among an order of cloistered nuns whose exposure to urban noises was limited. The hearing acuity of this group of women was the same as, and in some instances less than, that of a comparable population. Obviously, the question of the influence of aging on hearing loss has not been entirely settled.

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[1] The "C" network represents essentially a flat response between 50 to 10,000 HZ while the "A" network filters out a significant portion of the intensity below 500 HZ. It can be concluded that the source represented by the 95 dbC reading contains much more of its energy in the frequencies below 500 HZ than the source represented by the 80 dbC reading. Thus the frequency spectra of the two sources will be different.

A significant portion of our population has, in the past, been exposed to industrial noise in addition to urban noise. Hearing surveys (Figure 5) have, in fact, shown that hearing sensitivity is poorer in factory workers and other industrial groups than in a population with a minimal occupational exposure. An example of some noise levels associated with industrial operations are shown in Figures 6 and 7. It should be noted that the risk curves are higher in the lower frequencies, implying that the lower frequencies are less damaging than are the higher frequencies. It is significant, however, that industry has made rapid strides by the use of noise control techniques and hearing protection in its attempts to minimize this problem.

Noise levels in urban communities are on the rise. The causes are many, including expanding transportation and industry, population density, and increased construction. One of the most critical aspects of the urban noise problem involves the rapidly expanding transportation system, both highway and air travel. There are, at present, in excess of 100,000,000 vehicles on our highways, and the number of new vehicles increases every year. The problem is magnified by the tremendous increase in freeway systems, where both tire design and roadway composition contribute to noise output.

A few years ago, in a medium-size community, a thoroughfare was located adjacent to an office building which had

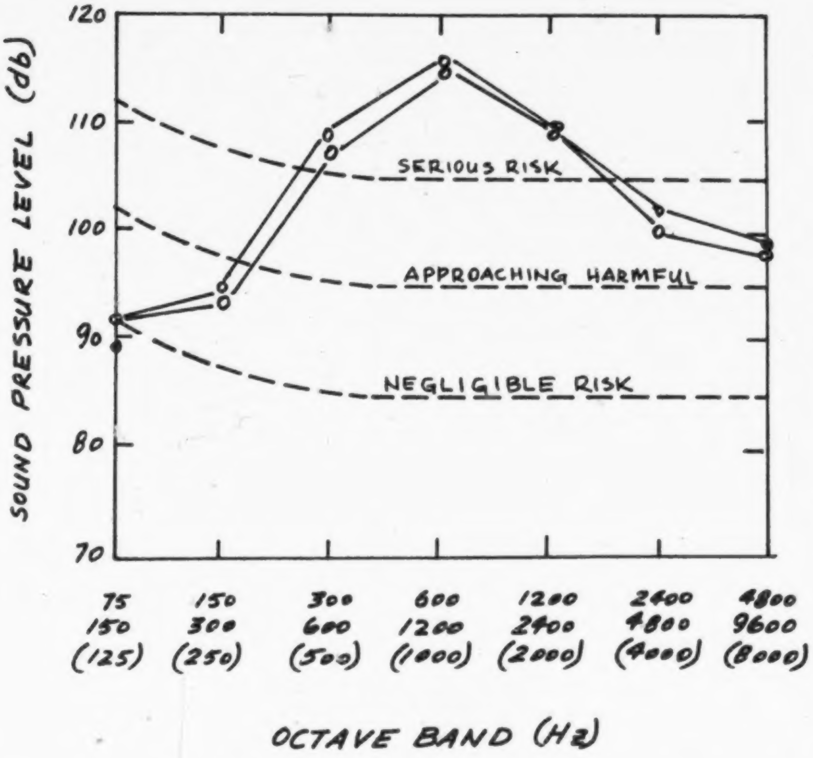

Figure 6. Noise levels associated with a planer, two feet from the machine.

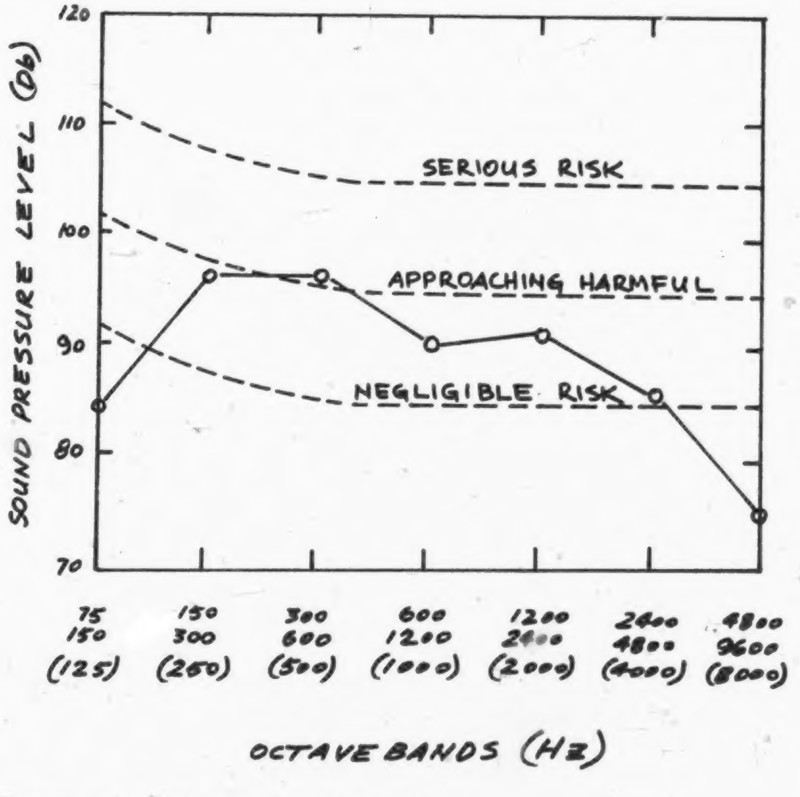

Figure 7. Noise levels from a Presto-log machine.

Noise Levels in Office Building and Street Adjacent to Building.

LOCATION	OVERALL SPL (dbC)
Second floor office	
Office "A" windows open	
Background—no traffic	58- 62
Light traffic	64- 72
Logging truck—empty	64- 80
Logging truck—loaded	95
Dump truck	84
Motorcycle	90- 94
Office "A" windows closed	
Background—no traffic	48- 58
Logging truck—loaded	80- 92
Outdoors—front of main entrance—no traffic	64- 68
Logging truck—loaded	100-104-110
Dump truck—loaded	100-102-105
Light traffic	80- 82
1949 sedan	90
Pick-up truck	86
Transit bus	87- 90
Motorcycle	90- 94

formerly been situated on a dead-end street. Following this roadway addition, noise levels within the building reached intensities as high as 95 dbC. (See the table.) Levels on the street corner reached 105 dbC. As a result of the noise, many tenants were forced to move.

In 1968 noise measurements were made in schoolrooms where student hearing screening tests were performed. Those schools located close to busy streets, freeways, and airports experienced noise levels 10 to 15 db above the levels in the other schools. Recently, continuous noise monitoring was accomplished in a school located immediately adjacent to a freeway. During the school day, background noise intensities in an empty classroom facing the freeway averaged between 70 to 74 dbC with maximum levels reaching 92 dbC.

THE PROBLEM of aircraft noise exists at every major airport in the world. Despite the attempts to limit jet engine noise, this problem will undoubtedly get more severe before adequate controls are promulgated. To the many persons clustered in homes and apartment buildings below or near the flight paths, life can be almost unbearable. E. Thomas Burnard, executive vice president of the Airport Operators Council International states:

> Aviation is still a fast growing industry in the U.S. In 1960 only 16 airports serviced jets; today there are 150 airports that receive jets. It is estimated that nearly 350 airports will service jets in 1970 and more than 500 airports will service jets by 1975.

Furthermore, Mr. Burnard, in a statement before the House Subcommittee on Transportation and Aeronautics, reported the following figures for aircraft and aircraft movements.

Year	Jet Air	Aircraft Movements (millions)
1960	224 (turbojets)	26
1966	896	47.8
1974	2240	95.6

The sonic boom controversy presents some very interesting aspects. A Special Study Group on Noise and Sonic Boom in Relation to Man reports that although the sonic boom from an SST would not be harmful to the human ear and although it has not been demonstrated that "startle" responses to the boom would have significant, harmful, psychological effects, it appears that the psychological, sociological, and political reactions of millions of people to the sonic-boom environment from the SST will be extremely adverse and may be of significant magnitude and prevalence to cause partial, if not complete, curtailment of the overland operation of an SST.

This study group indicated that the issues may be clarified through the following questions:

1. Can people "pay" physiologically and mentally the price of being exposed to from one to fifty booms per day from SST?
2. Should people "pay" the price of annoyance and discomfort from being exposed to the booms from a commercial SST?
3. Will the society of the United States "pay" the price of annoyance and discomfort from being exposed to the booms from a commercial SST?

Even in and around the home individuals are exposed to relatively high levels of noise. Responsibility for this assault rests with equipment and machinery including home workshop machines, TVs, radios, hi-fis, food mixers, air conditioners, washers, heating systems, vacuum cleaners, lawn mowers, etc. Noise levels at home may reach 100 db and even higher.

Measurements made by the author during a rock and roll dance reached a maximum of 122 dbC with the average intensity exceeding 104 dbC. A Florida physician concerned about his teen-aged daughter's difficulty in hearing, after attending a dance, selected a group of 10 teen-agers and tested their hearing an hour before a dance and again immediately after the dance. All suffered significant temporary hearing impairment, with the greatest impairment being in the high frequency range.

ONE can conclude that man is exposed to noise from many sources and that all of these sources contribute to the potential damaging effects. The question most often posed is: What can we do about noise? Here we have some answers via technology but many others that take us into the area of value judgments and considerations that are political, economic, or sociological in nature.

The recent interest in operational airport and aircraft noise and the future advent of supersonic transports, with the resulting sonic booms, has prompted a good deal of public attention to the problem of urban noise. As a consequence, there has been an increasing demand for legislation to combat excessive noise. In general, two types of laws have been used in attempts to control noise: nuisance laws and performance zoning codes. Nuisance laws are intended primarily to restrict annoying or unpleasant noise sources which are neither easily measured nor controlled by physical means. The most frequent forms use time limits to prohibit operation or the phrase "loud and annoying to persons of normal sensibilities." In many cases, the action is to prove that the complainer possesses other than normal sensibilities, which may be true or untrue.

Performance zoning codes typically specify the maximum allowable noise at a fixed point and provide relief by specifying limits for noise emitted from various activities. Nominally, these laws are proposed for promoting the public's health, safety, and general welfare while conserving property values and encouraging the most appropriate land use. Both nuisance laws and zoning codes have been used in a number of places in the United States. A review of most of these codes and laws indicates that they are usually ineffective or unenforceable. In either event, this approach has not proved realistic in controlling urban noise, at least at the level that I consider desirable.

Many common sources of noise are not amenable to control by these methods. The automotive vehicle, a major source of community pollution including noise, requires special attention as does aircraft noise and noise produced by mechanical devices. Here it becomes imperative that noise control be designed into the basic product. I hope that this can be accomplished voluntarily. If not, then I foresee that federal legislation will be required.

A look at the problem of the barking dog gives some insight into our attempts to control noise sources. Each year numerous complaints are registered because of noisy dogs. According to one local Humane Society, the barking dog and its relation as a public nuisance have long plagued the Humane Society and law-enforcement agencies. Existing laws tend to state that a barking dog may be a nuisance under certain conditions. No known law adequately defines a nuisance as it applies to the barking dog. The courts generally feel that a barking dog can only become a public nuisance if the following factors are part of the problem:

1. The dog must bark or howl.
2. The barking must be excessive.
3. The dog must annoy more than one individual in different households.
4. It must be at a time generally conceded that quiet should reign throughout the neighborhood.

When the Humane Society receives a complaint regarding a barking dog, a letter is sent to the owner informing him that his neighbors have complained and requesting that the nuisance be abated. If the dog owner refuses to comply, the complainants may, with the assistance of two others not of the same household and so affected, register their complaint at the "In Person Complaint Department" in the public safety building. This department may authorize court action.

There appears, however, to be some reluctance on the part of the judiciary to levy "stiff" fines on individuals whose animals have created a nuisance. It has been put forth by some that the way to solve the problem is for the judge to confiscate the animal. However, legally, this tends to be impossible as the animal is considered personal property. Most judges would not have the right to confiscate personal property from an individual as the result of a misdemeanor. It has been suggested that perhaps one way to solve the problem would be to issue a permit to keep the dog, rather than a license. Then, if the dog becomes a public nuisance, the "permit" could be revoked, thereby forcing the owner to remove the animal. Such a procedure would probably be acceptable but would still necessitate legal action.

AS YOU can well imagine, noise pollution control is an extremely complicated endeavor involving numerous variables and factors, many of which are still unknown. Much has been gained from past studies involving aircraft and industrial noise as well as viewpoints from other countries. With the possible exception of aircraft and vehicular noise, no set of maximum noise levels has as yet been adequately validated for use in community regulations. Control of community noise must be recognized and accepted as a major factor in urban planning and development. For this to be accomplished, it would be necessary to establish uniform standards and criteria for evaluating and controlling noise. Because noise is both a local and an area-wide problem, it seems to me that we will have to take the following steps: Appropriate local, state, and federal legislation must be forthcoming in order to support and effect compliance with standards; the manufacturers of mechanical equipment for all phases of use, domestic and industrial, must be made aware of the need to produce quieter equipment; construction codes must also recognize the need for acoustic treatment in homes and buildings.

A major effort will be required to solve the noise-abatement problem. It will be mandatory that many facets of our society—private, industrial, governmental, educational, and technical—assume greater responsibility in the quest for a quieter city. The only question now is . . . are we ready for the challenge? If we are not, then there is one consoling fact . . . as you the reader grow older, you will be disturbed less by noise . . . you will, of course, hear less. ☐

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HOW PLANTS FIGHT "MAN-MADE" POLLUTION

H. E. Heggestad

FOR MORE than a century, scientists and others have been concerned about plant injury caused by air pollution.[1] [7] It is only in the past few years, however, that there has been active interest in how plants help to fight pollution and to improve the quality of the air we breathe.

Robinette, a landscape architect of the University of Wisconsin, wrote in 1968, "At a time when there is much talk about air pollution, it appears that one of the greatest sources of natural air conditioning is being overlooked. Plant materials are among the most effective air conditioners in existence." [19]

Robinette's graphic drawings showed how plants can remove airborne particles and condition large volumes of air. He pointed out that air is slowed down as it moves through trees, causing precipitation of particulate impurities. At the same time, interaction between the air and surface of leaves results in removal of pollutants. During the day, when photosynthesis exceeds respiration, the oxygen supply of the air is replenished. Even unpleasant odors may be removed or masked with pleasant odors from vegetation.

Had others previously suggested the use of plants in this way? Search through the 1949 USDA Yearbook *Trees,* which contains articles on a wide range of subjects, reveals only related information.[2] Shelterbelts are used on the Great Plains to reduce wind erosion of soil, but they were not planted to catch airborne soil particles. The Yearbook does mention the trapping of snow by trees and the value to agriculture of the resulting increase in soil moisture. [21] Of course, if trees trap snow, they can also trap drifting soil. In addition, shelterbelts, by reducing wind, create more favorable conditions in orchards for pollination by bees. This wind reduction is a form of "air conditioning."

We have known for many years that plants also remove gaseous pollutants, such as hydrogen fluoride (HF), from the atmosphere. With only about one part per billion or less of HF in air, some plants accumulate in a single season several hundred parts per million of fluoride in foliage without visible effects. [11] Other plant species are injured when concentrations reach about 50 parts per million. Also, plants exposed to sulfur dioxide (SO_2) tend to increase in sulfur content.

As these examples show, information has been available on removal by plants of particles and gases from air, but little effort has been made so far to apply this information as a means of improving the environment.

Scope of the Problem

What is the magnitude of the air-pollution problem? In 1969, an estimated 281 million tons of pollutants were emitted into the atmosphere in the United States. [4] About one-eighth of this total of pollutants (35.2 million tons) were particulates, and the remainder were gaseous pollutants. The latter include carbon monoxide (151.4), sulfur oxides (33.4), hydrocarbons (37.4), and nitrogen oxides (23.8 million tons).

According to Altshuller [3], more than two billion tons of carbon dioxide (CO_2) are produced annually in the United States from fossil fuel consumption. While some of this CO_2 is removed by dissolving in seawater, it is

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[1] Pollution implies the introduction of any undesirable substance in the environment. Air pollution may include varying amounts of natural substances in air; for example, dust of volcanic origin, materials from living plants such as pollen, spores, fine seeds, terpenes, and other volatile products, many volatile products from biologic decay, etc. An assessment of this material is beyond the scope of this paper.

[2] With the public's renewed interest in trees, this USDA Yearbook can be a valuable information resource. For example, it provides a key to help identify trees and detailed recommendations as to which trees are adapted to different parts of the country. The book is out of print, but your library may have a copy.

Dr. Heggestad is leader, Plant Air Pollution Laboratory, Plant Science Research Division, Agricultural Research Service, U.S. Department of Agriculture, Beltsville, Maryland.

possible that plants also remove a significant quantity, though the exact amount is unknown. The level of CO_2 in the atmosphere is rising slightly, but there is no evidence at this time that the increase is of serious consequence.

It is primarily the particulates in air that reduce visibility and call our attention to air pollution. However, as the data above reveal, gaseous pollutants (excluding CO_2) are seven times greater, on a weight basis, than particulate pollutants. These figures do not include secondary pollutants produced by the action of sunlight on nitrogen dioxide (NO_2) and on certain hydrocarbons to form ozone (O_3), peroxyacetyl nitrate (PAN), and aldehydes such as formaldehyde.

The fact is, however, that ozone and PAN are more toxic to vegetation than are the primary pollutants involved in their formation. If ozone concentrations exceed one-tenth of a part per million, visible injury may result, especially on sensitive vegetation grown in the humid eastern United States. Even lower concentrations of PAN will cause acute injury to some species.

Table 1. Removal of NO_2 from Salt Lake Valley.[a]

NO_2 CONCENTRATION	REMOVAL RATE PER ACRE	REMOVAL RATE FROM THE VALLEY[b]
(24-hour average)	*(g/day)*	*(tons/day)*
2 pphm	72	33.00[c]
1 pphm	36	16.50
0.5 pphm	18	8.25

[a] From Tingey. [22]

[b] Based on 439,000 acres in Salt Lake Valley, 85 percent covered by vegetation in summer.

[c] This rate is equivalent to about 43 percent of estimated daily emissions.

Table 2. Solubility in water and pollutant uptake rate by alfalfa.[a]

POLLUTANT	UPTAKE RATE ALFALFA	SOLUBILITY AT 20°C
	(at 5 pphm) *(ul/min/m²)*	*(cc gas/ccH₂O)*
CO	0	0.02
NO	3	0.05
CO_2	10	0.88
O_3	50	0.26
NO_2	57	Decomposes
Cl_2	62	2.30
SO_2	85	39.4
HF	113	446.0

[a] From A. C. Hill. [8]

Air Cleansing Action by Plants

According to Rich *et al.* [17], removal of ozone by plants is regulated by the same factors that control the exchange of water vapor between the leaves and the atmosphere. The cuticle, or leaf surface, destroys very little ozone compared to that removed when the stomata (microscopic breathing pores) are opened, permitting ozone to enter the leaf.

Depending on the plant species, ozone concentration, and other factors, uptake of ozone by leaves often results in acute injury, premature aging, and senescence in plants. Even with severe injury to some leaves, removal of ozone from air continues as long as there are newer leaves that are functional. Of course, the primary function of leaves is to carry on photosynthesis, which involves intake of carbon dioxide and release of oxygen. The levels of oxygen in the atmosphere on a global basis have remained constant at 20.946 percent.

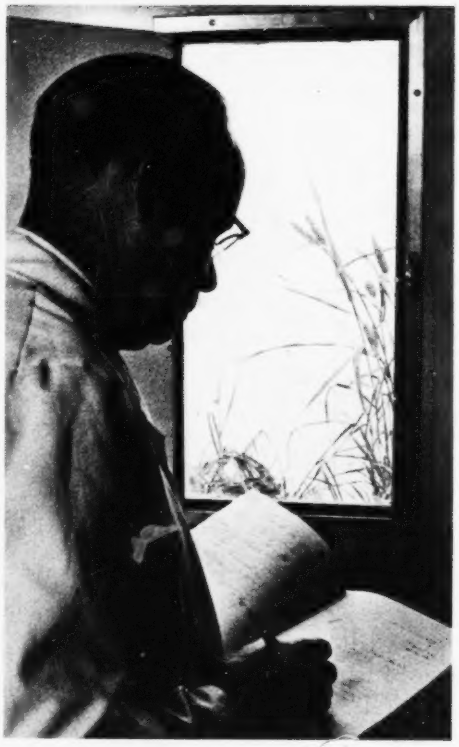
Greenbelts have been suggested to reduce gaseous and particulate air pollutants, as well as to provide other benefits. However, little quantitative information is available on the rates and significance of pollutant removal by plants. Most of the studies that have been made deal with sulfur dioxide; a few are concerned with nitrogen dioxide, fluoride, and other compounds.

According to Guderian of Germany [6], sulfur absorption is least when the concentrations of SO_2 are highest. Absorption of sulfur increases with decreasing concentrations of SO_2 and increasing exposure times. For example, absorption is greater when the exposure time is 20 minutes and concentration is 1 ppm than when the concentration is 2 ppm and the time is 10 minutes. Sulfur accumulations may occur even under pollution conditions which do not depress plant yield or the quality of plant products.

Results with Alfalfa and Oats

According to Tingey [22], who was a student with Hill [8] at the University of Utah, the initial uptake rate of NO_2 by alfalfa and oats was directly proportional to concentration in the range of 0 to 24 parts per hundred million. As length of exposure increased, the uptake remained linear with the range 0 to 8 pphm but became nonlinear and was reduced in the range 8 to 24 pphm. Alfalfa absorbed NO_2 in excess of 150 microliters per square meter of ground area per minute when exposed to 16 pphm NO_2. Oats showed uptake similar to that of alfalfa during the day, but uptake by this crop was erratic at night.

The diurnal uptake responses for NO_2 were similar to those for the assimilation of CO_2 and for transpiration. Data based on extrapolation from the NO_2 absorption data are presented in Table 1 to show estimated removal of NO_2 from the Salt Lake Valley. The removal of this amount of NO_2 by plants greatly reduces the amount available for photochemical reactions and production of ozone and PAN.



The author studies grasses in a growth chamber; they have been exposed to a mixture of ozone and sulfur dioxide.

Hill [8] provides quantitative information on removal of several pollutants by plants. Most of the studies were conducted in a laboratory chamber.

However, uptake of radioactive SO_2 by alfalfa in the chamber was about the same as in a field in Utah. At low concentrations of SO_2 (5 to 25 pphm), uptake was directly proportional to concentration. The rate of absorption was 17 microliters per square meter of ground area per minute for each part per hundred million of SO_2 in air.

Alfalfa removed gaseous pollutants in the following order: hydrogen fluoride most rapidly, followed by sulfur dioxide, chlorine, nitrogen dioxide, ozone, peroxyacetyl nitrate, and nitric oxide. (Table 2) The absorption rate of nitric oxide was very low, and it was not possible to detect any absorption of carbon monoxide. Pollutant uptake is influenced by wind velocity, height of plant canopy, and light intensity.

Hill also observed a close relation between the uptake of these pollutants and their solubility in water. (Table 2) A relationship between the uptake rate by plants and the water solubility of pollutants is not surprising, since pollutants entering the leaf contact cell surfaces, which are always moist. As stated by Hill, the ability to continue to absorb the pollutant for long periods of time depends upon the plant's ability to metabolize, translocate, or otherwise remove the pollutant from the absorbing solution. With respect to SO_2, when concentrations in the leaf are low, all the toxicant is oxidized to the relatively nontoxic sulfate form; but when concentrations are high, the sulfite ion accumulates, and there may be an increase in sulfurous acid.

Hill made no mention of hydrocarbon uptake by plants. About 70 percent of the hydrocarbons produced by man originate from transportation activities. They include acetylene (about 25 percent) and ethylene (20 percent). While these gases are reasonably soluble in water (1.00 cc acetylene and 0.25 cc ethylene per cc water, respectively), there is no evidence that they are absorbed by higher plants. [2]

Action of Woody Plants

In Europe, it has been established that spruce and pine needles absorbed SO_2 in winter as well as summer, and trees absorbed SO_2 at night as well as during the day. [15] The removal at night is probably due to absorption of the gas in surface moisture, since leaf stomata are normally closed in darkness. From a study involving 900 spruce trees it was learned that those which are most sensitive to injury by SO_2 removed more of the gas than did resistant trees. [16] Species of *Betula* (birch), *Fagus* (beech), and *Carpinus* (hornbeam) absorbed more SO_2 than did some species of *Acer* (maple), *Sorbus* (ash), and *Populus* (poplar). [13]

In England, significant reductions in atmospheric SO_2 were measured above a hawthorne hedge. [14] Intake of the gas was through stomata during the day, whereas at night absorption was primarily on wet surfaces. No loss of SO_2 from the air was measured when the hedge was too cold, too dry, wilting, or fumigated suddenly with a sharp increase in SO_2 for a few hours. Earlier studies in England with barley seedlings had revealed that the intake of radioactively labeled SO_2 was through stomata and was greatest when humidity was high. [20] Significant absorption occurred in thin films of water, whether on living or nonliving surfaces.

Roberts [18] in the United States confirms the earlier report from Europe [16] that ability to absorb SO_2 is related to the relative sensitivity of plant species to injury by the gas. The foliage of white birch, which is very sensitive, absorbed 48 percent more SO_2 per area of leaf surface than did the foliage of red swamp maple, a relatively tolerant species.

The capability of two tree species to remove dust was estimated in Germany. [12] One acre of beech forest removed 27.6 tons of dust compared to 12.9 tons by an acre of spruce forest. When the dust was washed off by rain, the filtering capacity of the trees was restored.

Role of the Soil

While vegetation serves as an important sink for some pollutants, the soil it grows in also plays a role in air purification. This observation seems to be especially important for gases, such as carbon monoxide (CO) and ethylene, which aren't absorbed by green plants. [2, 8, 9] Inman *et al.* [9, 10] demonstrated that soil was capable of absorbing CO and that its activity was due to the fungal microflora. This work showed that treatments such as heat sterilization and antibiotics destroyed the capacity of soil to remove CO from the surrounding air.

More than 200 different species and strains of fungi, yeasts, and bacteria were isolated from the potting soil. [10] Only 16 cultures, *all fungi,* proved capable of removing CO. Active fungi included *Penicillium digitatum, Penicillium restrictum, Mucor hiemalis, Haplosporangium parvum, Mortierella vesiculata,* and four species of *Aspergillus.* The investigators estimated that the total soil surface of the continental United States is capable of removing some 500 million metric tons of CO per year, or more than *twice* the estimated annual worldwide production of CO by man.

Fortunately, the ambient level of CO in the earth's atmosphere is remaining essentially constant, even though the world's oceans are significant natural sources of CO, and man's worldwide production of this poisonous gas is an estimated 151 million tons per year.

Similar studies by a team of workers at USDA and by workers elsewhere demonstrated that soil was also a sink for ethylene and other hydrocarbons. [1] However, while evidence was presented that microbes of some sort were required for absorption, their identity was not established. It is important to point out that soil is only one way for hydrocarbons to be removed from the atmosphere. Research has shown that a variety of hydrocarbons are degraded photochemically in the presence of oxides of nitrogen and by ozone.

Soil also acts as an effective sink for SO_2 and NO_2. At any rate, the soil becomes the ultimate sink for all pollutants as vegetation dies, falls, and decays in the soil. It seems reasonable to assume that the net activity of man will be reflected in the changed composition of soil and the water that flows from it into the final sink, the oceans.

Higher plants fight pollution in more

ways than by removing air pollutants. They hold topsoil in place and thereby reduce the amount of sediment and excess nutrients available to pollute our streams. Trees, shrubs, and tall grass make effective sound barriers and thus reduce noise pollution. Cook and Van Haverbeke [5] found that certain tree configurations reduced sound levels by half, while combinations of trees and grass cut noise to one-third compared with readings over equivalent distances of open hard surface.

Side Effects

Removal of particulates by plants has little, if any, effect on the vegetation itself, but plant removal of gaseous pollutants, such as ozone, PAN, high levels of sulfur dioxide, chlorine, etc., may cause injury to the plants. This damage is of economic importance, especially to growers of foliage plants where disfigured leaves are worthless. In addition, the accumulation of fluoride in forage crops can result in severe injury to animals eating the foliage, especially if it contains 50 ppm or more fluoride, and very little, if any, other feed is available. This problem has been identified, primarily in cattle, on farms down wind from some large fluoride-emitting industries.

Need for Greater Knowledge

We know that plant productivity can be reduced while the plants remove gaseous pollutants from the air. We need to know whether there is a reduction in plant productivity because of removal of gaseous pollutants by the soil. Also, does this process alter populations of fungi and other organisms needed in the soil to remove the pollutants? It should be noted that soil microbes also remove other pollutants in soil; for example, they detoxify certain pesticides.

There should be no question about the value of plants in controlling pollution, as well as in providing food and other material needs for our expanding population. Furthermore, in urban areas, trees and other plants provide an aesthetic link between man and his wilderness heritage. To satisfy these varied needs, an abundance of vegetation is essential. However, we should know more about the plants which are available to us and strive toward even greater functional and graceful use of our plant material.

There is sufficient diversity in plant species to meet our requirements. As partners with nature, we must be concerned about safeguarding this variability, as well as about utilizing it for our maximum benefit. We have a responsibility to wilderness areas, to maintain agricultural and forest lands, and to utilize the plants for the beautification of our cities and homes. We are reminded, also, that more should be known about the myriad species of soil microflora. They remove pollutants, decay organic matter, fix nitrogen, and otherwise enrich the soil, which in turn sustains our green plants. In addition, plants in oceans and other bodies of water help maintain oxygen reserves and supply food. It is on all the plants, and the environment which nurtures them, that we depend. □

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The Agricultural Research Service has two new publications offering classroom activities related to the work done by the Air Pollution Laboratory. They are *Air Pollution: A Threat to Plants* and *Testing for Air Pollution.* Both are available free by writing to the Educational Services Branch, Agricultural Research Service, Room 117, Building 307, Agricultural Research Center, Beltsville, Md. 20705.

TRACE ELEMENTS AND HEALTH

Wayne A. Pettyjohn

NEAR the close of World War II the badly damaged Japanese industrial machine was attempting to keep production in pace with military losses. Throughout several regions of the country, mining operations for heavy metals were proceeding with great haste. Good industrial waste-disposal practices were largely ignored. Along the upper reaches of the Zintsu River basin, milling wastes from a mine producing zinc, lead, and cadmium were dumped untreated into the river. Downstream, the contaminated water was used by farmers for drinking, cooking, and washing, as well as for the irrigation of rice fields. In a relatively short time, the yield from rice paddies irrigated with the muddy water began to decrease, and many of the rice plants showed evidence of stunted growth.

Sometime later it was recognized by Japanese health authorities that many people in the Zintsu basin, as well as throughout several similar mining regions, were suffering from a strange, sometimes fatal disease that caused the bones to become so thin and brittle that they easily snapped. The very painful affliction became known as "itae-itae," which literally means "ouch-ouch." Its cause was unknown.

In 1960 Jun Kobayashi [6], a Japanese researcher, examined bones and tissues of itae-itae patients. He found in them large concentrations of lead, zinc, and cadmium; consequently, he began to carry out experiments to test the effects of these elements on soil and plants. Chemical analyses showed that the rice plants had selectively absorbed and accumulated large amounts of these metals from the soil that had been contaminated by the irrigation water. The plants continued to absorb dangerous heavy metals from the contaminated soil years after the original pollution source had been removed.

Ingestion of the cadmium-contaminated rice by the local farmers apparently had caused osteomalacia, a bone disease. This disease causes bones to become thin and brittle because of a loss of calcium from the bone; the calcium is replaced by cadmium.

Similar studies were made on Tsushima Island, between Japan and Korea, where cadmium, zinc, and lead are mined. Itae-itae was discovered there also, although it had not been recognized previously—perhaps because early symptoms are more easily diagnosed as backache, headache, arthritis, rheumatism, or lumbago. Without some clue as to the cause of the disease, it is nearly impossible to diagnose.

Of special significance are the unusually low concentrations of the metallic elements in the contaminated water as compared to their concentrations in soil or plants. Sixty river samples from the Zintsu basin were chemically examined, but most of them contained *less* than 1 ppm (parts per million)[1] of cadmium and less than 50 ppm of zinc. Twenty-three mud samples, however, had a cadmium content as high as 620 ppm and zinc content as much as 62,000 ppm. That is, the sediment commonly contained 10 times more cadmium and 1,000 times more zinc than did the contaminated water! These metals accumulate in living plant and animal tissues and are introduced into a food

Dr. Pettyjohn is a professor of geology at The Ohio State University, Columbus, and is also an attorney. Portions of this article have appeared previously in The Ohio State University Chapter, Phi Delta Kappa News Letter, April 1970.

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[1] A unit of chemical measure; analogous to one penny in $10,000.

chain, which often leads to consumption by man.

Pollution and Trace Elements

Many industries throughout the world dispose of wastes containing heavy metals by dumping them into waterways. Just because a river contains industrial effluent, however, doesn't mean that the water is harmful. In fact, most of the elements found in waste waters are not as harmful as cadmium. Many of the trace elements, those that occur naturally in concentrations generally less than 1 ppm in natural waters, are essential to man's well-being. In many cases, however, there is only a small safety range between requirement and toxicity.

For example, cobalt is a component of vitamin B_{12}, which is essential to life. The lack of minute amounts of copper in the diet results in nutritional anemia in infants, but large concentrations may cause liver damage. Iron is an essential component of the protein in red blood cells, and iron deficiency anemia may create several physiological problems. But when iron is present in concentrations greater than about 1 ppm, the water will taste so metallic as to be unpalatable. On the other hand, even minor amounts of substances such as arsenic, lead, cadmium, mercury, and selenium may cause serious adverse physiological effects in man.

A great deal of national and international concern was generated following the mercury poisoning of several members of the Huckleby family in New Mexico—and from the discovery of mercury-bearing fish in Lakes St. Clair and Erie. In each of the above cases the source of the toxic material was traced, found, and identified. In New Mexico, the source was an organomercury compound used as a preharvest fungicidal seed-dressing for corn. The treated corn was fed to pigs, and the pork was consumed by the family. The toxic effect of the mercury, which remained in the pork tissues even after cooking, resulted in severe brain damage to two children. In Lakes St. Clair and Erie, mercury contamination was traced to factories disposing of their effluent directly into Lake St Clair. The subsequent ban on fishing in this lake and in the western part of Lake Erie profoundly affected the commercial fishermen in that area, as well as many recreational enterprises.

Table 1. Public Health Service recommended limit of selected trace elements in drinking water supplies and the concentration of a few trace elements in municipal water supplies at five major cities in the U.S.

TRACE ELEMENT	PHS LIMIT PARTS PER MILLION	CLEVELAND	GARY	SAN JOSE	MOBILE	WICHITA
Arsenic	.05	—	—	—	—	—
Barium	1.0	.032	.032	.084	.025	.034
Cadmium	.01	—	—	—	—	—
Chromium	.05	.0035	.002	.001	.0019	ND
Fluoride	variable	—	—	—	—	—
Lead	.05	.0079	.02	.011	.001	ND
Selenium	.01	—	—	—	—	—
Silver	.05	.00023	.00054	.00032	0.00009	ND
Aluminum	None	.25	.096	.049	—	.094
Cobalt	None	ND	ND	ND	ND	ND
Copper	1.0	.006	.0017	.003	.00062	.0012
Zinc	5.0	ND	ND	ND	ND	ND

— not looked for, ND not detected.

C. N. Dorfor and Edith Becker, "Public Water Supplies of the 100 Largest Cities in the United States." U.S. Geological Survey Water Supply Paper 1812. 1962. P. 364.

Widespread publication of these shocking facts by the news media served to forewarn the general public of the possible toxic effects of some industrial effluents. In a matter of weeks, various state and federal agencies began to look at the concentrations of minor elements in water supplies.

Many people assume that the presence of toxic or potentially toxic trace elements in water and food has only recently been discovered. This is actually far from the case. The phrase "mad as a hatter" was coined in the nineteenth century and refers to brain damage effects arising from the use of mercury compounds used to treat felt in hat making. Reports describing "Minamata" disease, a form of mercury poisoning, began to appear in Japanese journals in 1959, following the death of more than forty people. The problems at Minamata Bay in Japan began as early as 1953. [11] In fact, scientific and medical reports from throughout the world for years have pointed out that many trace elements are common in waste waters; that they tend to be removed from the water and mud by plants and by absorption on silt and clay; and that to determine the presence of such elements it was not enough to test only the water. Those who believe the mercury problems in Lakes St. Clair and Erie are solved are sadly mistaken. The mercury is in the mud on the bottom of the lakes and rivers where it will be slowly released to plant and animal life for decades.

All water contains some trace elements, but their significance in metabolism is a long way from being completely understood in spite of years of work and research by health scientists. Charles Dorfor and Edith Becker compiled a mass of chemical data on raw and finished water supplies from one hundred of the largest cities in the United States: Every sample contained some trace elements. [2] In some cases sufficient information is available to set up specific water quality standards, but in others the standards are no more than mere educated guesses that can serve as only temporary guidelines. (See Table 1.)

Arsenic

Arsenic is a well-known poison that occurs naturally in many rocks, minerals, and soils. It may be present in relatively large magnitudes in coal and, when released to the atmosphere as flue dust, may act as nuclei for the accumulation of moisture, which in turn may lead to arsenic-rich rain.

Several industrial processes involved with ceramics, tanneries, chemicals, and metal preparation require the use of arsenic, but the manufacture of pesticides consumes the largest amount of this element.

Members of the Kansas Geological Survey have found 10 to 70 ppm of arsenic in presoaks and household detergents. [1] Even in the Kansas River the amount of arsenic closely approaches the recommended limit as set by the Public Health Service. Its presence is due to waste-water disposal from municipal treatment plants and septic tanks. Arsenic compounds are common in surface water, owing to the disposal of industrial and municipal effluent and as a result of runoff of rain water and snow melt, which erodes soil containing arsenic pesticides. Investigations by the Illinois State Geological Survey show that the uppermost part of the sediment on the floor of the southern part of Lake Michigan contains arsenic ranging in concentration from 5 to 30 ppm. [9] The presence of the arsenic has been attributed to man's activities in the watershed surrounding the lake.

As indicated, the presence of arsenic in water supplies is not solely the result of pollution. Arsenic poisoning leading to sickness and death among cattle in New Zealand was attributed to drinking water containing large concentrations of arsenic of natural origin. [4] Naturally occurring arsenic compounds in waters from the western part of the United States have also been reported.

Small amounts of arsenic are ingested by humans every day. It occurs naturally in food, especially fruit and vegetables, and as a residue of agricultural spraying. It is also present in public drinking supplies.

The toxicity of arsenic to humans is well known. The element accumulates in the body, causing arsenosis. The effects of the poison, when ingested in small amounts, appear very slowly; it may take several years for the poisoning to become apparent. Chronic arsenosis, in its most extreme form, causes death. Arsenic may be carcinogenic, and it is known to affect the liver and heart.

Lead

Perhaps the most toxic element in the heavy metal series is lead. Lead is a cumulative poison. Many children suffer the effects of lead poisoning after eating small flakes of lead-base paint. Lead poisoning may produce mental retardation, palsy, and perhaps severe personality and behavioral problems.

Moonshine whiskey is a source of lead poisoning among unborn or nursing infants as well as adults. The lead dissolves from soldered connections in automobile radiators, which are used for distilling. Children born from mothers addicted to moonshine may show retarded growth before birth, as well as spastic and other nervous disturbances after birth. The editors of *Environment* report that lead has been found in 96 percent of the moonshine whiskey sampled in the southeastern part of the United States; of this about 30 percent contained as much as 1 ppm. [3]

Another source of lead in drinking waters—more prevalent in the past than in the present, thanks to the now widespread home use of copper tubing—is the solution of lead pipes. It has been suggested that one of the reasons for the decline of the Roman empire was lead poisoning. Apparently, many of the patricians had water piped into their homes and baths through lead pipes; they drank their wine from lead containers. The constant ingestion of this lead-bearing water and wine may have caused mental retardation of the ruling class.

The major source of lead in the atmosphere is the combustion of lead-based gasoline. It has long been known that emission of lead-containing automobile exhaust along major highways has contributed to the unusually high concentrations of lead in roadside plants. In addition to automotive exhaust, lead arsenate sprays and fumes from certain manufacturing plants, such as smelter fumes, can also introduce large amounts of lead into the atmosphere, soil, and vegetation. Near major highways in British Columbia and in southern England, cereals and vegetables contain 5 to 10 times the normal amount of lead. In both Finland and the United States, food crops grown near major highways contain 4 to 20 times the normal amount of lead. [12] These high concentrations are mainly the result of pollution.

Localized excessive concentrations of trace elements led H. V. Warren, a geologist at the University of British Columbia, and his co-workers to point out that "abnormal concentrations of copper, zinc and lead, can, in a geographical sense, be related with areas where the over-all mortality rate and the mortality rate for cancer of the stomach are well above average." [13] They also investigated several regions in England and Scandinavia and found that in every area where multiple sclerosis is especially prevalent, garden and farm products contained abnormal amounts of lead.

Two researchers at The Ohio State University found that in all but one of 27 samples of snow collected over a 20-square mile area in Columbus, Ohio, the concentration of lead exceeded the Public Health Service recommended limit for drinking water. Lead concentrations in the January 1970 snow ranged between 0.05 and 1.09 ppm. It was suggested that automobile exhaust was the probable source of the lead. [5]

Much of the 12-million pounds of lead shot expended annually by hunters comes to rest on the bottom of shallow lakes and swamps. Eventually the pellets become food for unsuspecting water fowl, causing mass mortality from lead poisoning. It has been estimated that about one million birds die annually from ingesting lead shot.

On the other hand, abnormal concentrations of lead in the environment cannot always be attributed to pollution. Some local soils are known to contain a great deal, because the bedrock from which the soil was derived also contains large natural amounts of lead.

Several common lead compounds may be major sources of this toxic heavy metal in water supplies. Lead acetate is used in the printing and dyeing industry. The insecticide used mainly for the control of the gypsy moth and boll weevil contains lead arsenate, which could act as a major source of soil pollution. Lead chloride is used in the manufacture of lead-base paints and in solder. The high concentration of lead in some sediment samples below some effluent outfalls near oil refineries is probably the result of lead tetraethyl—the substance that also causes lead to occur in large concentrations in the atmosphere through the burning of gasoline.

Zinc

Various types of zinc salts are used in galvanizing and in the manufacturing of paint pigments, pharmaceuticals, cosmetics, and several types of insecticides. The solubility of many of these salts in water accounts for their presence in industrial waste.

Seawater contains an average of only .01 ppm of zinc [7], but soils derived from a zinc-rich rock may contain several hundreds of parts per million. The zinc in the soil may, in turn, be removed by plants, which may concentrate it to as much as 20,000 ppm.

Except at very high concentrations, zinc alone has no known adverse physiological effects upon man. But acid drinks, such as lemonade or fruit juices, should not be made or mixed with zinc-bearing water because certain organic zinc compounds may be poisonous.

On the other hand, zinc is both essential and beneficial in human nutrition. It is a component of insulin and is involved in the utilization of carbohydrates and protein. Some evidence seems to indicate that it aids in the healing of wounds. [10] Zinc is not stored in the body and very little is known about its deficiency in man, but zinc deficiency does affect animal reproduction. Some common vegetables may not contain sufficient zinc for dietary requirements, and, coupled with the general decline in the use of galvanized materials in plumbing and cooking utensils, the availablity of zinc to humans and other animals has been greatly reduced.

On the other hand, zinc is highly toxic to fish and other aquatic animals. Apparently, the zinc may act as an internal poison or it may form an insoluble compound with the mucus that covers the gills of fish. [8]

Large concentrations of zinc in drinking water are undesirable for several reasons. Zinc produces an objectionable taste; it may cause water to appear milky or, upon boiling, to appear to have a greasy surface scum.

Conclusion

Many different kinds of trace elements in hundreds of different chemical combinations await us in food, water, and air. Some are toxic, some are not; but little is known of possible side effects that can occur following their intake over prolonged periods. Trace elements, by definition, are present in only minute amounts. Yet even small quantities can cause serious health problems. Illnesses caused by them are difficult to diagnose, and it may require years for physiological changes to appear. Once they contaminate the soil they will remain there to be slowly removed by plants and animals for perhaps centuries. Only rarely are food and water supplies chemically examined for them. At least, let us beware.

Class Projects

Interesting class projects might be to attempt to determine the amounts and kinds of trace elements that occur in the municipal water supply or in waste waters released to the environment by local industries. These projects would not be easy for several reasons. First, the chemical determination of trace substances requires both expensive and highly sophisticated instrumentation that is commonly not available to colleges, much less high schools. Second, even the local water-treatment plant operator may have no idea as to the types or concentrations of trace elements occurring in the municipal supply. Third, industries are not likely to give out information concerning either the quantity of waste water discharged or its chemical composition. Nonetheless, projects of this type would tend to point out some of the many problems facing state, federal, and local pollution control and health agencies as well as interested environmentalists. ☐

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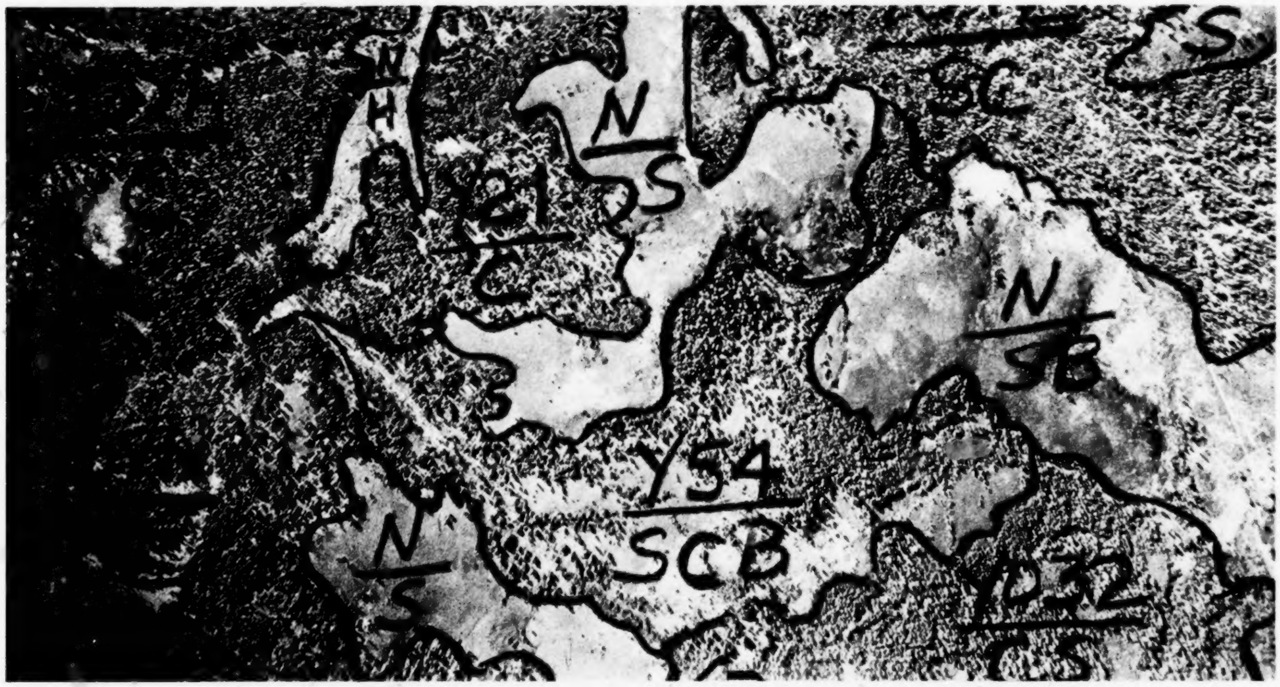

Figure 1. Vertical aerial photograph of a wildland area in which vegetation types have been accurately classified and delineated. As a result, the area has been "stratified" into essentially homogeneous units as regards: (1) age class of timber (left half of numerator), e.g., O = old, Y = young; (2) density of saw-log size timber (first digit of numerator) and of all timber, regardless of size (second digit), e.g., 1 signifies 80 to 100 percent of ground is covered by crowns of trees; (3) vegetation elements present (denominator), e.g. C = commercial conifer, H = hardwood, etc. N in numerator indicates nontimber site, i.e., soil too poor to grow timber at a sufficiently rapid rate for commercial purposes.

TAKING INVENTORY OF CROPLANDS AND WILDLANDS

Robert N. Colwell

TODAY'S YOUTH, more than those of any previous generation, should be knowledgeable about the world's croplands and wildlands and insistent that these lands be wisely managed. Each generation comes to realize that as the world's population increases there is a commensurate increase in the amount of the earth's surface that is occupied by people, buildings, and transportation facilities and a consequent decrease in the area occupied by the world's cropland and wildland. But it will be during the lifetime of today's youth that this relentless trend will lead for the first time to a critical situation for all mankind.

Not just two, but three factors are working in concert to hasten the coming of that critical day when the demand for goods and services from croplands and wildlands will exceed the supply from those lands. We already have mentioned the rapidly increasing number of people to be served and the decreasing land area from which their demands might be satisfied. The third factor is the increase in demand per capita.

In this regard we need to recognize that the "affluent society" is only one segment of the world's population that asks each year for more and more "creature comforts," including those that can only be provided by croplands and wildlands (e.g., better food, clothing, and shelter; more opportunities for recreation in rural and wildland environments). A much larger segment of the world's population are the millions and perhaps even billions of people of the world who have had a standard of living barely above the subsistence level. In the last few years, the voice of these people has become so pronounced that social scientists have coined a new term to account for the phenomenon. Perhaps you already have heard that term. It is known as "the awareness of the have nots."

Dr. Colwell is a professor of forestry at the University of California in Berkeley. This article is adapted from his address to the 1969 Youth Conference on the Atom in Chicago last October.

The oncoming generation will need to cope in every possible way with the problem of making the *supply* of resources from croplands and wildlands meet the ever-increasing *demand* for them. The resources of our dwindling croplands and wildlands must be managed as intelligently as possible. A first step leading to such management is that of obtaining accurate inventories of the resources associated with these lands, including their soils, water, and vegetation.

Some highly ingenious means have been developed recently for making such inventories periodically on croplands and wildlands. This increased ability to acquire accurate, timely inventory data can lead to the better management of such lands, thereby helping to solve some of man's most pressing problems of supply and demand.

Improved resource inventories lead to improved resource management through three successive steps. These are: *inventory, analysis,* and *operation.*

In the *inventory* step (the one with which most of my remaining comments will deal), an effort is made to determine "how much" of "what" is "where" throughout the area that is to be managed. The "what" in this instance usually refers to specific resources within the cropland or wildland area. Among such resources are the soils, water, minerals, vegetation, and usually certain topographic factors, such as slope, aspect, elevation, and drainage.

In the *analysis* step, certain decisions are made as to how the resources are to be managed. Such decisions are arrived at by considering two kinds of information: (1) information as to the amount and disposition of resources within the area that is to be managed (such information having been obtained in the preceding inventory step); and (2) information as to the costs likely to be incurred and the benefits likely to accrue by applying to these resources each of several management measures. For example, will the benefit exceed the cost if we build a dam, control an infestation of weeds, or apply fertilizers to impoverished soils?

In the *operations* step, decisions reached in the analysis step are implemented. On the one hand, these decisions are not likely to be wise ones unless the two preceding steps (inventory and analysis) have been properly executed. On the other hand, regardless of the care with which steps (1) and (2) have been executed, nothing of consequence has been done until the third step is taken. The objective is to achieve more intelligent management and consequently to increase the yield of croplands and wildlands. Inventory and analysis do nothing unless action follows.

AS OUR first example of an inventory technique, let us consider one of the important current projects of the United States Forest Service—taking an inventory of the nation's timber resource. As authorized by Congress, this inventory (known as the Forest Survey) includes among other things the determination of our forest land acreage, the existing timber volumes on those lands, and present potential timber growth.

The process of obtaining these facts begins with a classification of vegetation made on aerial photos taken from an aircraft flying three or four miles above the earth. The classification serves in three ways. First, it provides the area inventory of the various timber and other vegetation types. Second, it gives a "stratification" of timber stands that minimizes the ground sampling needed for a reliable estimate of timber volumes and growth, and third, it provides an "in place" delineation of the vegetation classes that makes the survey locally useful.

Entirely from a study of aerial photographs, the following kinds of information are obtained: (a) the kind of vegetation cover or other condition occupying the land; (b) the age structure of tree stands, based on the proportions of the various age classes of timber present; (c) the densities of timber stands and of all woody vegetation, based on the proportion of the ground area that is obscured by the foliage of this vegetation as seen on the vertical aerial photograph; and (d) the segregation of timber croplands from other lands. Then, from ground observations aided by whatever the photos can reveal, the species composition of the vegetational areas is obtained. Other classifications made are indirectly related to the aerial photos.

An example of the photo classification that is done in the Forest Service Timber Inventory appears in Figure 1. By quickly accomplishing the classification that is shown here, it is possible for the photo interpreter to reduce the amount of on-the-ground timber survey to approximately 1/1000 of what it previously had to be. This is not only a saving in time and money but is also of tremendous value in that it is possible to inventory all of the resources in a vast forest area quickly. One can, therefore, arrive at an intelligent management plan far more speedily than if old, conventional, on-the-ground timber-cruising techniques were used without the aid of aerial photography.

MANAGERS of cropland and wildland resources realize that accurate inventories are necessary for livestock as well as for vegetation and other resources. Among the inventory data desired by livestock managers are: livestock counts in each field by kind of animal (e.g., cattle, sheep), use (e.g., dairy cattle, beef cattle), breed, sex, age, and vigor. In addition, they need an estimate of each factor affecting the animal-carrying capacity of an area, including the amount, palatability, accessibility, and nutritive value of each species of forage; the location and state of repair of corrals and livestock fences; and the location of stock-poisoning plants, noxious weeds, springs, salt grounds, stock-watering places, rodent concentrations, highly erodable sites, and areas in need of reseeding.

Again we have considered whether the use of aerial photographs might improve the inventory procedure. It seemed probable to those of us who were asked by the Department of Agriculture to conduct these studies that the completeness and accuracy of livestock interpretation made on small-scale aerial photos might be improved if some basic studies were first performed with large-scale *simulated* aerial photos. Such simulated photos might be

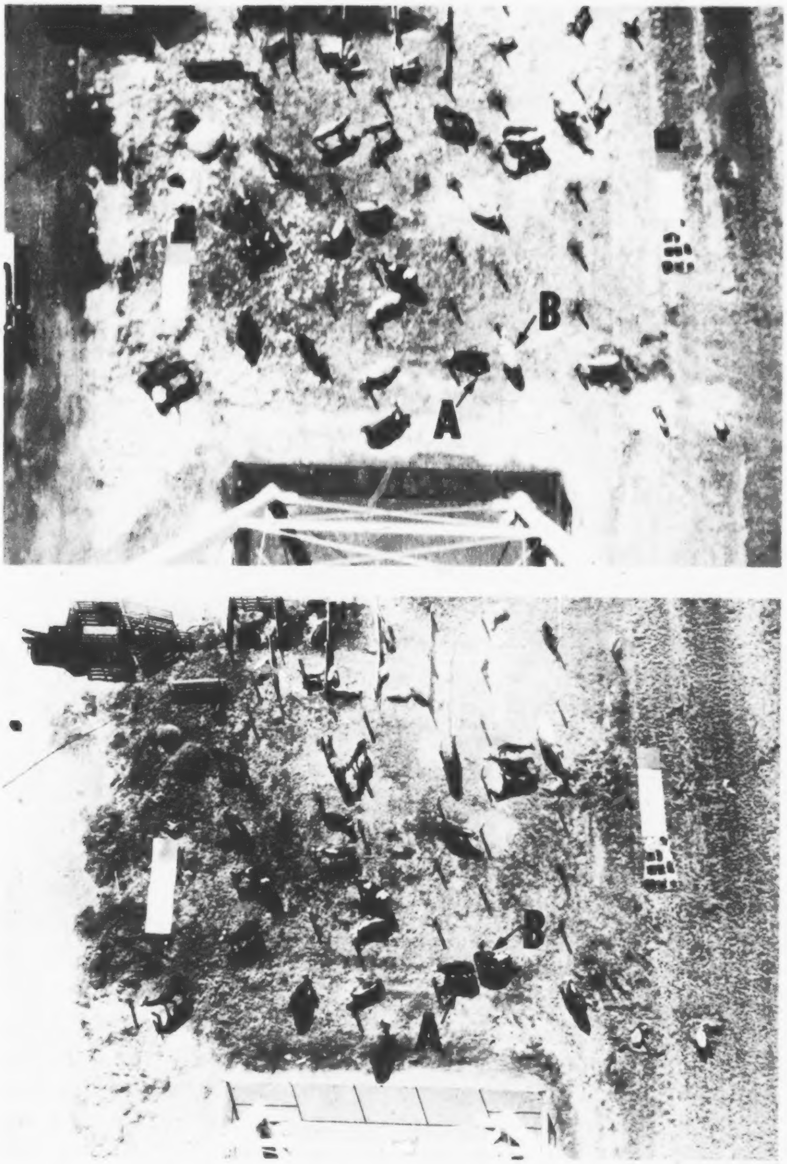

Figure 2. Simulated vertical aerial photographs of various kinds of livestock taken from the catwalk of a water tower. The camera station was 150 feet above the animals. From careful study of the animals and their shadows, a photo interpreter can learn to recognize type of animal (cattle, sheep, pigs, goats) and sometimes breed, sex, and vigor. Note on the bottom photo (taken with infrared film) that there is a tone difference between animals labeled "A" and "B", which are, respectively, a Hereford and the product of a Hereford-Angus cross. However, these two beef animals cannot be differentiated on the top photo which was taken with panchromatic film.

taken under carefully controlled conditions from the top of a water tower, for example, with representative livestock on display near the base of the tower. The near-vertical photos thus obtained would permit the photo interpreter to make a realistic and detailed analysis of each animal image and of the shadow cast by the animal. Many photos of this livestock array could be taken from the tower quite economically, at various sun angles, with various film-filter combinations, and with varying but precisely known amounts of stereoscopic parallax. Furthermore, the animals composing this array could be made to assume various stances representative of those encountered on operational aerial photos. It seemed likely that a study of this photography and of actual aerial photography obtained of the same target array at the same time would indicate the most suitable film-filter combination and the best time of day for photographing livestock. The aerial and water-tower photography would also contain valuable examples for the construction of photo interpretation reference materials for the identification of livestock.

Once this work had been performed, simulated operational photography of representative range and pasture lands could be flown to optimum specifications. Then livestock inventories could be attempted on this photography under truly optimum conditions. It seemed necessary to strive for such conditions because the aerial photo interpretation of livestock is at best a difficult task.

The two photos comprising Figure 2 are representative of the more than two hundred vertical photographs taken from the catwalk of the water tower on the Davis campus of the University of California. They illustrate how livestock of various kinds, breeds, sizes, and sexes appear in the near vertical view when photographed from an altitude of 150 feet with a camera having a focal length of 6 inches. Of these two photos, the one on the bottom (taken with infrared film) permits the photo interpreter to distinguish between Hereford cattle and cattle which are the offspring of a Hereford-Angus cross. By tones registered by the dark parts of the labeled animals, they can be differentiated as to breed. On the upper of this pair of photos (taken with panchromatic film), such tonal separation cannot be made. This observation is representative of the many that can be made from photos when the objective is to determine the most suitable film-filter combination for use in livestock inventories.

It is interesting to note in Figure 2 the very close similarity between the shadow of each animal and the corresponding appearance which the animal itself would present to a ground observer. Thus these examples provide information as to both the vertical and horizontal configuration of each type of animal. There is a far better prospect of identifying each animal as to type, breed, sex, age, and vigor if both the vertical and the horizontal views are considered. The photo interpreter who realizes this important fact will take pains to interpret both the animal and its shadow whenever possible.

The livestock inventory tests just described are now in the process of being evaluated. Preliminary findings indicate that on aerial photos taken from altitudes as high as six to eight thousand feet, it may soon be possible to make livestock inventories on a nationwide basis more quickly and accurately than through use of conventional on-the-ground enumerations.

A VERTICAL photo of a vineyard of Thompson seedless grapes, taken shortly after the grapes have been harvested for raisin production, is shown in Figure 3. Trays on which the grapes have been laid for drying are readily seen between the rows of vines. In order to appreciate the need for counting the trays both quickly and accurately on aerial photos, the following brief statement is needed as to the nature and purpose of a raisin-lay survey.

A raisin-lay survey is a determination of the acreage of vineyards within which grapes have been harvested for raisin production and the total fresh weight of these harvested grapes. In the San Joaquin Valley of California, both raisins and brandy for dessert wine are commonly produced from the same variety of grapes. The raisin grapes are laid out for drying several weeks before the grapes for wine production are harvested. If, in any given year, the quantities of grapes devoted to raisin production and to wine production can be

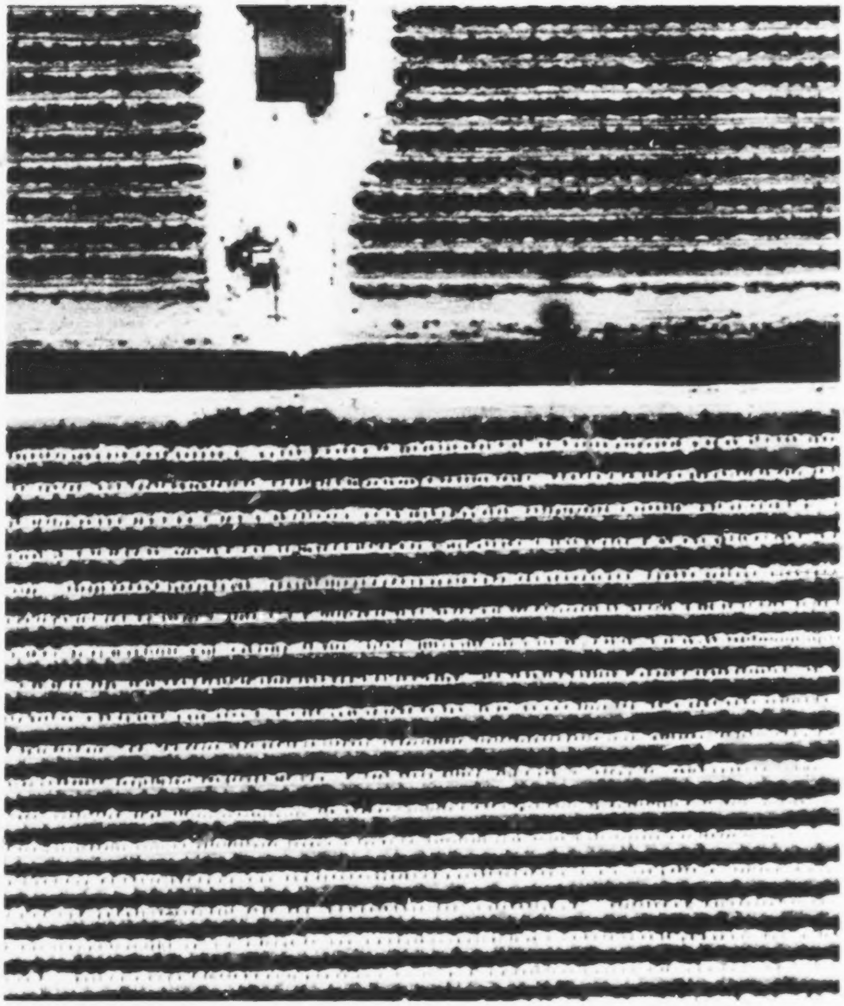

Figure 3. Vertical aerial photograph showing a portion of a vineyard in the San Joaquin Valley of California shortly after grapes have been harvested for raisin-lay production. Trays between the rows of vines are readily seen.

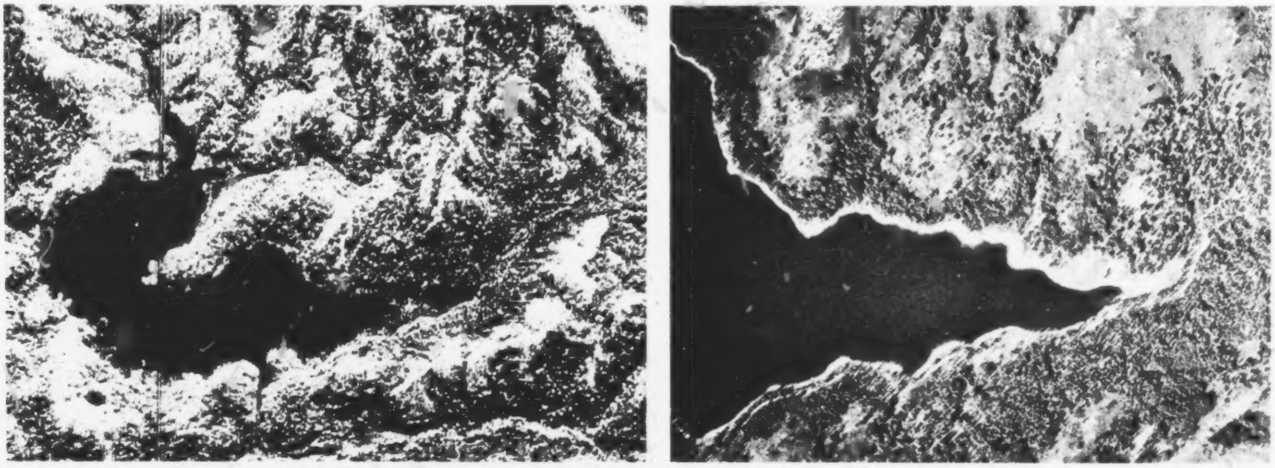

Figure 4. A photo-like image obtained with side-looking airborne radar equipment (left) on which a lake and major landforms and vegetation types are recognizable. Unlike conventional aerial photography (right), radar imagery is obtainable at night and during cloudy or rainy weather.

made to conform to demands, the needs of the consumer will be better met and the producers will realize greater profits. From the information obtained through the raisin-lay surveys, the rate at which raisins are being made can be determined and compared with a predetermined optimum rate. Grape growers and the producers of wine and raisins can use these periodic reports, during any given harvest season to: determine whether too many or too few grapes are being laid to supply the raisin market; make unofficial forecasts of the total raisin production for the season; and estimate what quantity of grapes will be available that season for wine production. With the aid of these surveys, both the grape and wine industries can be operated on a more stable and profitable basis.

Until recently, raisin-lay surveys were attempted strictly by means of on-the-ground observations. Since nearly 1,000 square miles of vineyards had to be sampled, these methods proved to be too slow, too expensive, and too inaccurate. The present procedure, employing aerial photography, overcomes these difficulties. The photos are taken on each of seven suitably-spaced dates during the raisin-producing period so that a determination can be made of when enough raisins have been produced. Beginning at about 10 AM on each of the seven selected dates, a photographic aircraft begins systematically to photograph the entire raisin-producing area from an altitude of 17,000 ft. Approximately four hours later, the photography has been completed. Once the photographic plane has landed, the film is promptly processed, and a short time later photo interpreters start counting raisin trays. Even though limiting their counts to small sample areas, they work throughout the night counting trays on the photographs so that producers can be given the needed information by the following morning. In one recent year the accurate information thus provided is credited by the producers with having saved them five million dollars. Each year the making of seven such raisin-lay surveys is considered to be an eminently worthwhile effort.

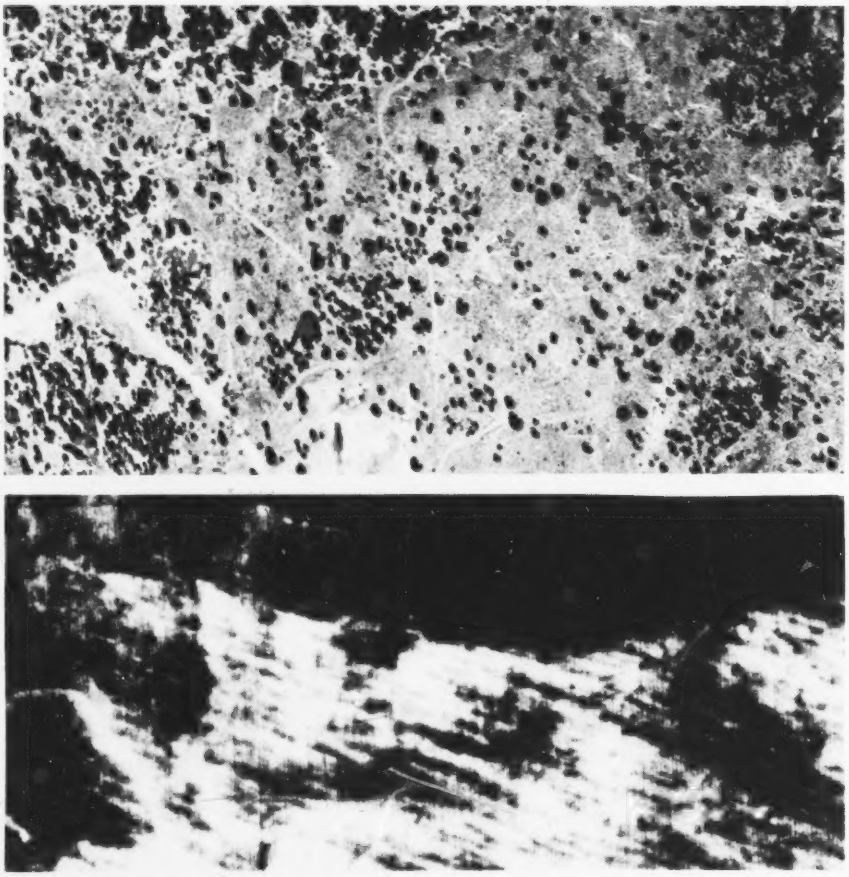

Figure 5. Two images of the same area, using panchromatic film in an aerial camera (top) and a thermal infrared sensing element in an optical mechanical scanner (bottom). The top photo maps light reflectance differences while the bottom photo maps thermal emission differences. More information is obtainable from a study of these two types of images in concert than from a study of either type alone.

AN ILLUSTRATION of a wild land area in the Sierra Nevada mountains of California as imaged with a special kind of remote-sensing device known as side-looking airborne radar is shown in Figure 4 (left). The image was obtained from an aircraft flying at an altitude of approximately 5,000 feet. Notice that the quality of the image is sufficiently good to compare favorably with a conventional aerial photograph (right). The importance of this type of capability results from the fact that side-looking airborne radar equipment can produce images of this quality either day or night and regardless of weather conditions. This capability, therefore, is especially valuable when the desire is to obtain information about areas that are obscured a great deal of the time by adverse weather conditions as well as areas which, for a variety of reasons, may need to be studied during the night-time hours.

An additional advantage of radar imagery of this high quality results from its ability to reveal certain features more clearly than those features might be seen even on high-quality conventional aerial photographs. An example shown in this figure is the drainage network of streams and canyons. These can be clearly seen on the radar image. The longer wavelengths of energy used in forming this radar image, as compared with the wavelengths used in forming a conventional aerial photograph, apparently permit the features that are obscured by foliage of the trees to be more clearly seen. It is not known for sure whether these longer wavelengths actually penetrate the leaves themselves or are able to bend around them, but in either event, better registration of ground detail beneath the foliage is the net effect.

Thermal infrared energy also travels at wavelengths longer than those of visible light. An example of a photo-like image that can be formed with modern thermal infrared remote-sensing equipment is seen in Figure 5. In this same scene, a conventional photo taken from an aircraft is provided so that a direct comparison can be made. It will be noted that certain features (such as the important soil boundary running from left to right across the middle of these two illustrations) are better seen in the infrared image than in the conventional photograph. Certain other details, however, are far better seen on the conventional photograph. This illustrates one of the many examples of obtaining what is known as "multiband imagery." Such imagery is obtained in each of several wavelength bands of the spectrum.

This same advantage of multiband imagery applies to imagery obtained from earth-orbiting vehicles. This fact is well illustrated in Figure 6. Shown here are two photographs taken by the Apollo 9 astronauts at an altitude of approximately 100 miles. The Salton Sea in Southern California is clearly seen on both of these photographs as a very large, dark-toned feature occupying most of the upper left quadrant in the two photos. Immediately below it is a heavily vegetated area known as the Imperial Valley, in which important agricultural crops are being grown. It will be noted that the agricultural crops themselves appear dark in tone on the uppermost photo (taken with panchromatic film) while they appear light in tone on the lowermost photo (taken with infrared film). No other features in the entire area exhibit this same "tone signature." Consequently, even though only a limited amount of detail can be seen on these two photographs, one is able to readily differentiate agricultural vegetation from all other features. When these two photographs are suitably enlarged, it is possible to determine, for each field within the Imperial Valley, whether or not it contained healthy vegetation at the time when a given set of photographs was taken. In order to exploit this capability, photo interpreters have developed for areas such as Imperial Valley what are known as "crop calendars."

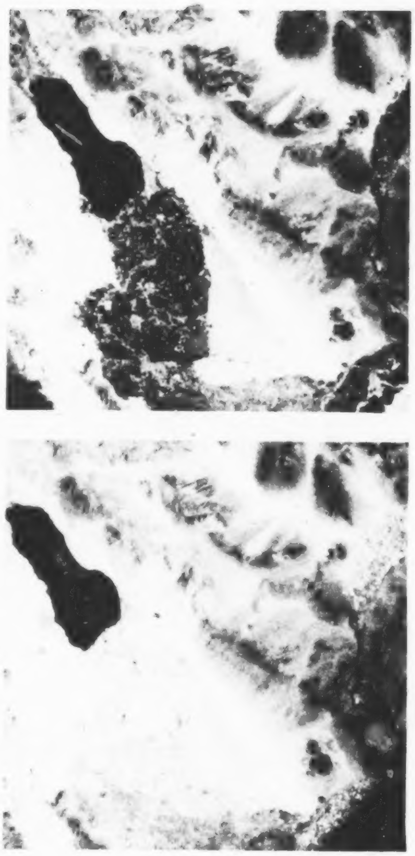

Figure 6. Multiband space photographs taken from an altitude of approximately 100 miles by the Apollo 9 astronauts in March 1969. The top photo was taken with panchromatic film through a light-red filter so that only energy from the visible red wavelength band was used. The bottom photo was taken with infrared-sensitive film and a very dark red filter so that only energy in the infrared wavelength band (just beyond the visible red) was used.

Crop calendars indicate the months of the year when various types of crops are planted and the months when those crops reach maturity and are harvested. For example, barley, which is commonly grown in this area, normally is planted in the month of November and harvested three months later. Sugar beets normally are planted in August or September and harvested approximately nine months later. Cotton is never planted in this area until after the barley has been harvested and hence is ordinarily planted in May or June. In order to exploit this fact as an aid to the identification of agricultural crops, field-by-field, the photo interpreter must have not only the crop calendar but also space photographs such as those shown in Figure 6. These were taken on each of several different dates throughout the year. By comparing the appearance of the fields in terms of presence or absence of vegetation on each of these "sequential photographs," the photo interpreter can identify each type of crop. Since the photograph itself is a map for all practical purposes, the photo interpreter also is able to determine the acreage of each field and in this way the total acreage devoted to each type of crop. Then, by making limited observations on the ground as to the yield of product from each type of crop that is being obtained per acre, simple calculations provide the photo interpreter with total yield by product for the entire area that is to be inventoried.

This kind of information is of tremendous value to those who seek to determine, year after year, what the total yield is likely to be in each vast agricultural basin for each type of crop. The information is needed by those who decide when we will have a surplus or a deficiency in any particular crop, thereby necessitating export or import of that crop. Others who need this kind of information as far in advance as possible are the farm workers who will be employed to harvest the various crops, workers in the canning and storage industries, workers in the transportation industry, and in the various industries which produce such chemicals for agricultural use as fertilizers, herbicides, fungicides, and insecticides. There is increasing evidence that this kind of information can be obtained in the near future on photography obtained sequentially from earth orbital satellites, especially if photography is taken with the right photographic films. Thus we see, in this specific example, an illustration of the value of making an inventory with either aerial or space photography in order that important management decisions can be arrived at and implemented.

Hopefully, many of today's youth will give serious thought to the service which they might render to all mankind by becoming experts at using aerial and space photography to inventory croplands and wildlands. ☐

Paul J. Fitzgerald

THE "GREEN REVOLUTION"– SELECTION AND GENETIC VARIANTS

PROSPECTS of mass famine in some developing nations have dramatically focused attention on the urgent need for improved crop production throughout the world. Scientists from both public and private organizations are meeting this challenge with missionary zeal. Their recent accomplishments in India, Pakistan, Turkey, and Africa have been beyond our most optimistic expectations. Hope is replacing despair in many food-deficit countries. What is the secret of this "green revolution?" Have we now found a formula that works?

In my opinion there are two major reasons for the unprecedented increases in the production of cereals in developing countries: superior plant breeding and the "package concept." Plant breeding as used in this discussion implies much more than the art of visual selection. It includes a working knowledge of genetics, statistics, and plant pathology. Plant breeders have always relied on differences or genetic variation among plants. They have usually had as an objective the combining within a single variety of favorable genetic traits, such as high yield, resistance to disease and insect pests, resistance to lodging, resistance to shattering (tenacity of grain in the chaff), specific quality characteristics, growth habit, and the like. Progress has generally been stepwise, with breeding and selection occurring in parallel lines of improvement for different characters.

A significant breakthrough in wheat breeding occurred with the introduction of the very short, stiff-strawed wheats from Japan in 1946 and their subsequent introduction into the Agriculture Research Service (ARS)-Washington State cooperative wheat improvement program. The Japanese variety, Norin 10, was crossed to the U.S. varieties Brevor and Baart. Selections from these crosses provided the basic germ plasm for Gaines and Nu-

Dr. Fitzgerald is assistant chief of the Cereal Crops Research Branch, Crops Research Division, Agricultural Research Service, USDA, Beltsville, Maryland.

gaines, the former a world record holder with 209 bushels per acre in Washington.

This same germ plasm was introduced into the Rockefeller-Mexican program and provided part of the basic parental material of the series of improved semidwarf varieties that have performed almost unbelievably in many diverse parts of the world. The significant characteristic of the semidwarf varieties has been their ability to grow under very high levels of fertility and under irrigation without lodging. Because these varieties tiller (shoot) profusely and produce heads of normal size, their yielding potential is usually much greater than standard height varieties. In addition, the Mexican semidwarf wheats possess a gene for photoperiod insensitivity that permits a very wide adaptation in many latitudes.

A similar story can be told for the remarkable advances in rice breeding by scientists at the International Rice Research Institute in the Philippines. These workers also recognized the potentials of shorter varieties and successfully combined the semidwarf germ plasm with the traditional types to produce the widely acclaimed IR-8 and IR-5 varieties. While these varieties do not show a performance superiority in the USA and lack quality characteristics for our market, they have virtually revolutionized rice production in several traditional rice-producing countries. Because of their production characteristic and associated improved management practices, grain production has been increased two- to threefold in some areas.

The understanding of genetic variation and the manipulation thereof has laid the foundation of a sound corn-breeding program in Kenya with influence radiating throughout eastern Africa. The combination of the vigorous Central American germ plasm with the native types in Kenya and effective selection procedures produced varietal hybrids with yield increases up to 400 percent. The corn-breeding effort in this small country, with associated cultural practices and seed production, in a few years changed Kenya from a corn-deficit to a corn-surplus country.

NOT ALL the advances in production can be ascribed to plant breeding alone. The "package concept" has been a highly significant factor in all cereal crops wherever yields have improved. This concept embodies several logical principles. You start with the best variety available; plant it in a well-prepared seedbed properly treated with the right kind and amount of fertilizer, and insecticide or herbicide as needed; and where water is available, apply timely and controlled irrigations. This concept of maximizing all production inputs has avoided many of the early failures to bring about sustained improvements by breeders or soil scientists working alone. It is generally recognized that the concept must go beyond the production phase if the agricultural sector is to become a vital economic factor in a country. It must also include the manufacture of machinery, production of fertilizer and agricultural chemicals, a seed industry, storage facilities, transportation, and production credit. These things are happening in many countries.

NEW production records are being recorded each year in many countries from the use of new crop varieties responsive to the new and improved management practices. The fear of starvation is greatly reduced for the moment, but the critical problem of protein quality and quantity has been brought into focus. Here, too, there is hope. With the discovery by Edwin T. Mertz and Oliver E. Nelson in 1963 that the mutant genes opaque-2 and floury-2 in corn were associated with much improved levels of the essential amino acids, lysine and tryptophane (usually in short supply in normal corn), breeding for improved nutrition in grain crops immediately became high-priority work. Research at many locations has produced experimental lines of corn with lysine and tryptophane content double that in normal corn. In addition, total protein content has been improved. The feeding value of opaque-2 corn to swine has been shown to be equal to skimmed milk, greatly reducing the need of expensive protein supplement. Extensive evaluation trials with high lysine corn in Central and South America by personnel of the International Maize and Wheat Improvement Center (CIMMYT) have demonstrated the improved nutritive value to both humans and livestock. The potential for improved human nutrition in this region, where 30 to 60 percent of the daily caloric intake is from corn, staggers the imagination. Additional improvement in yielding capacity of high-lysine lines is needed before they are widely accepted in the United States.

The discovery of genes for improved protein quality in corn triggered similar efforts in other grain crops. Considerable effort by CIMMYT and by the ARS-Nebraska wheat-improvement program is directed toward the improvement of protein in wheat. Total protein has been markedly improved, but selections with promising levels of lysine and other deficit amino acids have been difficult to stabilize. Breeding more nutritive wheats appears feasible, but the breeding and testing will be demanding. To date there has been no strong indication that high lysine mutants exist in rice and sorghum, although the chemistry of the proteins of sorghum suggests that a search for mutants similar to opaque-2 is justified. Oats do not have the same imbalance of amino acids common to other cereals, but striking improvements in total protein appear possible with the recent introduction of *Avena sterilis* lines from Israel. High levels of resistance to crown and stem rusts were bonuses in this discovery.

Indeed, these are exciting times to be a plant breeder. It is generally estimated that the breeder has made a major contribution in averting immediate and massive famine. His continued effectiveness in contributing to adequate food production will depend largely on his success in making new combinations of genetic traits in new varieties. Where known sources of germ plasm are not adequate, it will be necessary to search for new types. The collection, identification, and maintenance of genetic stocks of all crops is vital to any sustained effort to improve world food production. □

OCEANOGRAPHY FOR THE 1970s

Donald V. Hansen

Dr. Hansen is director, Physical Oceanography Laboratory, Atlantic Oceanographic and Meteorological Laboratories, National Oceanic and Atmospheric Administration, Miami, Florida. This paper was presented at a Sunoco Science Seminar at the NSTA annual convention in Cincinnati, Ohio, March 14, 1970.

SIGNS abound that the 1970s are to be a decade of concern for the environment. These are favorable signs for those interested in the scientific study of the oceans. As concern and displeasure grow over the unsightliness of environmental pollution, we are beginning to see that knowledge of the behavior of the water-covered portion of the earth is an essential ingredient to rational decisions on the local scale and the key to avoiding potential planetary disasters.

Most oceanographic research has been and continues to be done by a few relatively affluent nations, notably, Canada, France, Germany, Japan, the United Kingdom, the United States, and Russia. The oceanographic capability of this country has grown most impressively in the last two decades, especially during the post-Sputnik scientific renaissance. About 1960, oceanography became a glamour field of science, and a considerable national effort was put into strengthening it. Due to the considerable investment required for facilities and equipment and due to the lack of immediate economic return, most oceanographic research has been supported by the federal government either in the name of basic research or national defense. In 1966, President Johnson announced a new focus on clearer objectives in marine affairs and asked for establishment of a commission to chart the new course. But in spite of initial nigh expectations and numerous studies of how the objectives were to be reached, the oceanographic community has grown increasingly frustrated. Debate over objectives and their implementation continues, and more recently there has been flagging support for oceanography, a condition shared with many other fields of science.

While the nation's investment in oceanography has been small relative to that for space technology and other

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Menhaden, a type of herring, is extremely abundant off the east coast of the U.S.

major programs, progress has been good. Discoveries have been made which are at least as important as those in space. We have reached a point where progress in the 1970s will be determined more by what we choose to do than by what we are able to do. It is appropriate, therefore, to attempt to place our expectation of ocean benefits in perspective so that the slender resources may be used wisely.

Ocean Resources—Present Perspective

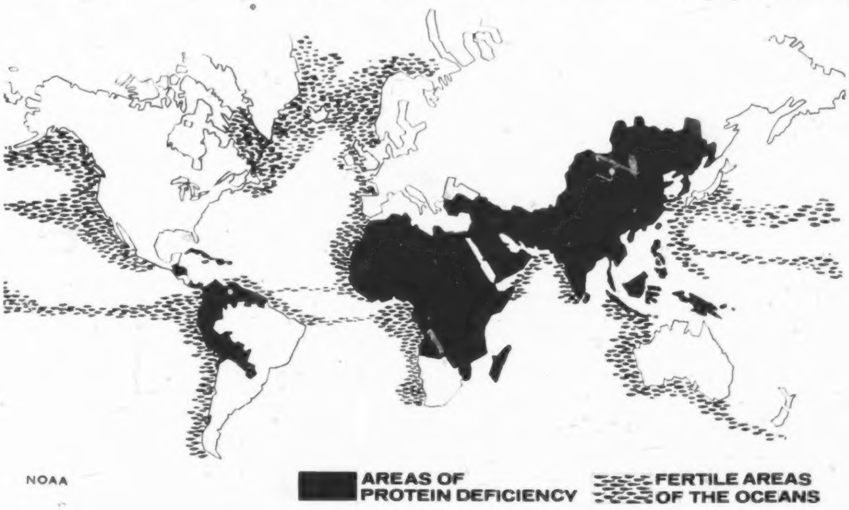
The "wealth of the ocean" is doubtless commonly oversold. Man's major activity in the ocean—71 percent or so of the earth's surface—is still the simple matter of making his way about it. The world's ocean freight bill is around $15 billion annually. Shipping is not an exploitable resource in the sense of extracting useful substances from the ocean, but substantial benefits are to be gained by further improving and extending this most efficient means of transport to new regions. The 1970 cruise of the super-tanker *Manhattan* was an ambitious industrial experiment in this area.

The monetary value of the world fish and shellfish catch is on the order of half the world freight bill. One commonly hears expectations that the "limitless" stock of food from the sea will feed untold billions of future earth population. The great magnitude of standing stock of some unexploited species is indeed misleading; it is well to remember in this connection the bison herds that once populated the Great Plains. But in more dispassionate moments we accept that the ocean and its contents are, like the rest of our planet, finite. Fishermen know that with modern technology and the size of modern fleets, even pelagic stocks are easily overfished. The history of a number of important fisheries shows that the catch increases with effort up to a point, after which the return begins to decline. Herring and cod of the North Atlantic and the global whale fishery are prime examples.

The solar energy requirement for photosynthesis certainly sets an upper limit on sustainable food yields, but conditions of life in the ocean, such as generally lower fertility in the photic zone, make the ocean less productive than comparable land areas. Due to the larger ocean area, the total biological production appears to be about equal to that on land. But conditions for life in the sea force much of the product to be microscopic and so dispersed that it is not likely to be harvestable directly. There are no pelagic trees or cereals, hence the product must be concentrated to harvestable packets by intermediate organisms. Evaluation of this complex process is difficult, but present estimates suggest that the harvest could be increased by from two to five times present levels.

The value of gas and petroleum from offshore wells is now perhaps three-quarters that of fisheries and is growing very rapidly. For example, approximately 20 percent of U.S. petroleum resources and 15 percent of our production is from offshore sources. Production of other minerals from oceanic sources is still relatively minor, but it is certain to increase tremendously as high-grade ores on land run out.

For the United States, the order of things is somewhat peculiar in that marine-oriented recreation ranks near transportation in dollar value; offshore petroleum production is flourishing; but our fisheries constitute a disaster area. Waste disposal probably would rank quite high if one could put a realistic dollar value on it, which we as a nation have been disinclined to do. The ability of the ocean to absorb large but finite amounts of waste material is



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certainly a major resource, whether we like to think about it or not.

Once resources are defined, the major impact of oceanography will be its contribution to efficiency of operations in the marine realm, including provision of guidelines to avoid ecological disasters. Decimation of exploited species is of immediate concern to fishermen, but more subtle problems can involve us all. It has been estimated that perhaps two-thirds of all the DDT ever produced still exists and is making its way to the oceans. Likewise, herbicides and lead and other heavy metal compounds may be accumulating to the detriment of primary biological productivity in the ocean.

Another subtle and complicated problem concerns the relationship between climate and the oceans. Most members of the scientific community are aware that the increasing amounts of carbon dioxide released by burning fossil fuels could alter the atmosphere's radiation balance and result in global climate change. Less generally recognized, however, is the fact that the ocean is the planet's great reservoir of carbon dioxide, as well as water. Upon dissolving in the ocean, carbon dioxide becomes available for photosynthesis. It reacts with water to provide the carbonate ions used by calcareous organisms. In consequence, the ocean contains 50 times as much carbon dioxide as does the atmosphere, and more than 90 percent of a perturbation of atmospheric carbon dioxide will ultimately reside in the ocean. The question, then, is how rapidly atmospheric carbon dioxide is equilibrated with the ocean and distributed within the great mass of its waters. This rate will determine how much carbon dioxide can safely be released to the atmosphere.

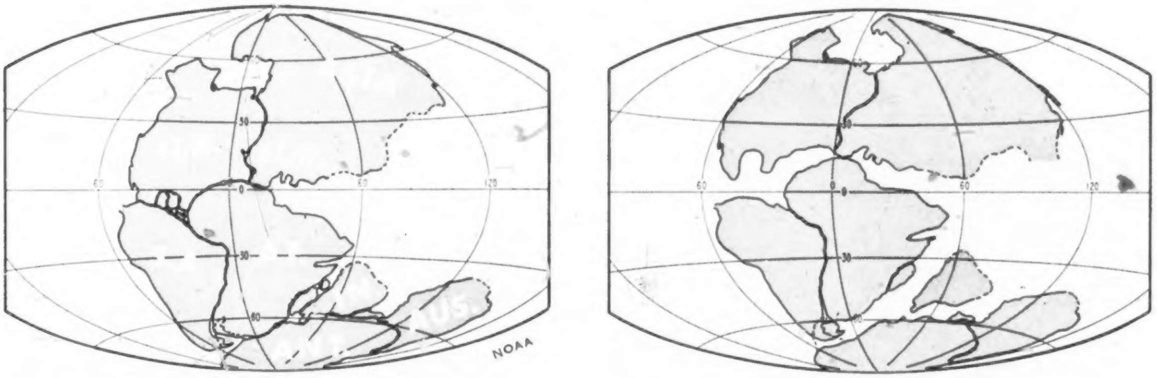
I turn attention now to some recent activities and new insights which affect our ability to understand the ocean and to use its resources wisely.

Ocean Basins

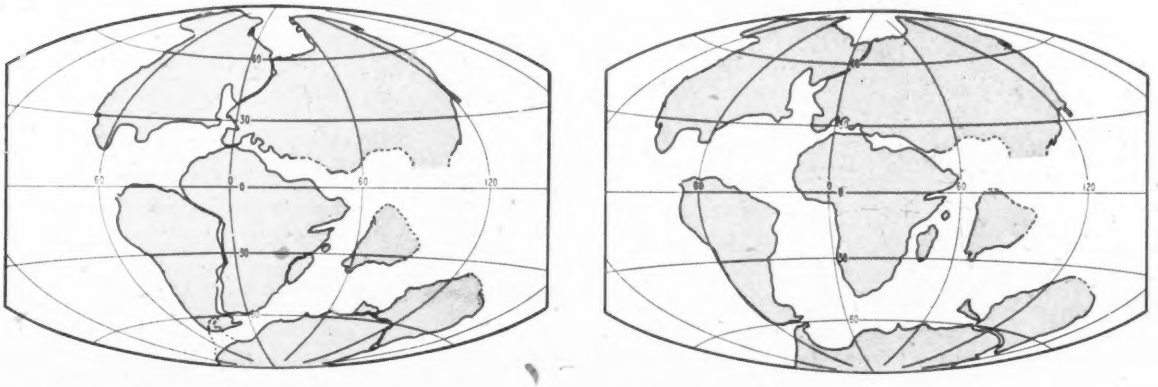
A revolution in geologic concepts is underway and that revolution is fired by oceanographic research. The concept of continental drift, advanced by the German geologist Alfred Lothar Wegener about a half century ago, long stood in poor repute, primarily because there were no apparent forces capable of pushing a continent. Geophysical surveys of the ocean basins are now providing strong support for this theory. Present interpretations indicate that new ocean floor material emerges from within the earth along the midocean ridges. The material is conveyed across the ocean basin and disappears beneath the continents, shifting the continents in the process.

A primary line of evidence for the continental drift concept is the pattern

Robert S. Dietz and John C. Holden of the National Oceanic and Atmospheric Administration recently worked out this sequence of maps that for the first time identify the 200-million-year journey the continents have made across the face of the earth.



PERMIAN - 225 million years ago **TRIASSIC** - 200 million years ago



JURASSIC - 135 million years ago **CRETACEOUS** - 65 million years ago

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It is being increasingly recognized that the behaviors of the two global fluids, ocean and atmosphere, are inseparable and must, therefore, be studied as a whole.

Solar radiation is the basic energy source for the circulation of both ocean and atmosphere. Studies like BOMEX (the Barbados Oceanographic and Meteorological Experiment) seek to analyze the various kinds of interactions.

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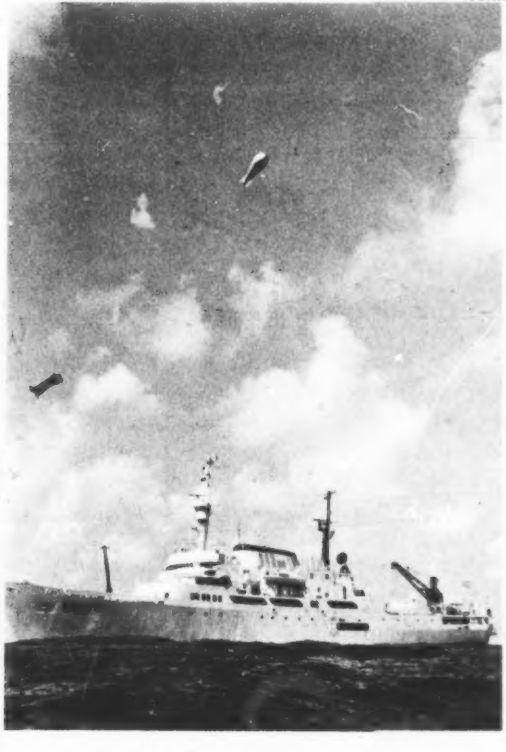


of magnetic anomalies. It appears that the magnetic field of the earth has reversed polarity a number of times. As igneous rock emerges from within the earth it freezes-in the contemporary magnetic orientation, which is retained thereafter. As the sea floor moves away from the point of emergence, the record of magnetic reversals is preserved as though by a geophysical tape recorder. Events of the last few years are providing powerful new confirmation of these hypotheses.

The most exciting results have come from the investigations of the *Glomar Challenger*, a deep-ocean drilling ship operated by Scripps Institution of Oceanography under contract with the National Science Foundation. The first year's work of the *Glomar Challenger* resulted in discovery of oil and gas in the central Gulf of Mexico (the first such discovery in a deep-sea environment), and only small amounts of ferromanganese nodules in sediments at depth; these are both findings of immense practical value. This project has been extended until 1973 and is expected to produce further exciting results on the origin and nature of the ocean basins.

Short years ago we expected to find a complete history of the earth locked in the ocean sediments, undisturbed by the erosion and turmoil through which the continental record of geologic history must be read. Now it appears that the ocean floor is in fact younger than the continents and younger than the ocean itself.

Sea-Air Interaction

Another scientific endeavor that came into being in the last decade and will likely continue is large-scale study of sea-air interaction. At present, we are primarily interested in the influence of the oceans on weather, but it is generally accepted that the behaviors of the two fluids, ocean and atmosphere, are inseparable and must be studied as a whole. The basic energy source for the circulation of both mediums is solar radiation. This radiation is not efficiently absorbed by the atmosphere; rather, it penetrates to the earth's surface (predominantly the ocean) from which it is relayed to the atmosphere as longer wave radiation and latent heat of water vapor evaporated from the oceans. The ocean circulation in turn is driven by wind stress and exchanges of heat and water with the atmosphere. The ensuing circulations serve to transfer heat from low latitudes (where incoming radiation exceeds outgoing radiation at the top of the atmosphere) to high latitudes where there is a radiational deficit. The early studies are being done in the tropics where the energy flow is initiated.

Two such experiments were undertaken in 1969: the Atlantic Tradewind Experiment (ATEX), which involved four ships—two from the United Kingdom and one each from Germany and the United States—for a three-week period in March and April; and the Barbados Oceanographic and Meteorological Experiment (BOMEX), which used, in all, 12 ships, 28 airplanes, and 1,500 scientists. Preliminary results from BOMEX indicate that more solar radiation is absorbed in the atmosphere than has been thought and that the ocean currents are very different than indicated on charts.

The enormous number of environmental measurements made will require

U.S. NAVY PHOTO

The sinking of the Titanic in 1912 renewed interest in ocean currents because of their importance in transporting icebergs into the North American shipping lanes.

months or years for complete analysis. The results of these and larger projects to come will be appearing throughout the 1970s.

Decade of Ocean Exploration

Presidents Johnson and Nixon both endorsed U.S. leadership in an International Decade of Ocean Exploration (IDOE) in the 1970s. It is unclear how vigorously IDOE will be pursued because of our current social, military, and economic commitments and because a substantial contribution from other countries is required. At least one project for IDOE, the Cooperative Investigation of the Caribbean and Adjacent Regions (CICAR) appears to be gaining momentum and may serve as a prototype for later projects in larger ocean basins. It also appears to be of considerable value for the U.S. interest in the Gulf of Mexico. The Gulf receives almost two-thirds of the waterborne natural, industrial, and agricultural pollutants of the United States, making it a likely candidate for pollution disaster. The flow of the Gulf Stream into and out of the Gulf is sufficient to completely renew Gulf waters in 30 months, but the extent to which the deep water and water of the western Gulf participate in this circulation is almost entirely unknown.

Ocean Currents

One of the central problems of physical oceanography has been and remains that of transports—the movement of materials and energy by ocean currents. During the birth of the industrial age and before the decline of the sailing ship in commerce, the transport of greatest interest was that of surface ships. (The speeds of ocean currents were not inconsiderable compared to those of the sailing vessels.) In the twentieth century the transports of greatest interest are much more subtle. The current favorites are transport of heat as it influences global weather and climate, transport of chemical nutrients as it influences fisheries, and transport of a variety of troublesome substances introduced by the activities of man.

Closure of the Suez Canal has also rekindled interest in the effects of currents on shipping. Experiments are in progress on optimizing use of the Gulf Stream to help tankers save a few hours between Gulf of Mexico oil fields and U.S. East Coast cities, but the real interest is in finding methods applicable for the run around Africa.

I will outline briefly some of the milestones in evolution of knowledge of currents in the North Atlantic Ocean, which, with the possible exception of the waters around Japan, is the best known major ocean region. I will focus on the Gulf Stream system as a familiar point of reference for North Americans and the most salient feature of the surface circulation of the North Atlantic.

Early Charting of the Gulf Stream

A general knowledge of the surface circulation and of the Gulf Stream was used by the Spanish as early as 1519 in their annual voyages to and from the New World. Although a considerable body of practical knowledge was used by the great American whale fishery, the Stream was not charted for more systematic use until the 1780s. At that time, Benjamin Franklin, in his capacity as Postmaster General, had a chart of the Gulf Stream off New England drawn by Timothy Folger, a Nantucket whaler. The chart was printed by the General Post Office for use by the mail packets. This empirical approach was picked up and systematized by Matthew Fontaine Maury—now frequently cited as the father of American oceanography—who collated the information appearing in navigation logs of sailing ships, using the records of their drift to infer the ocean surface currents. In use of such data, averages of a large number of observations must be taken because of the imprecision of individual observations. Though many of the interesting and useful variations of the current are obscured by averaging, this technique is still the primary source of knowledge of the surface circulation in all published oceanic current charts.

During the same period the Coast and Geodetic Survey, directed by Alexander Bache, Franklin's grandson and an eminent scientist, among others, began a remarkable series of investigations of the Gulf Stream off the southeastern United States, from the Caribbean to Cape Hatteras. The Stream and its variations were metered directly from anchored ships—a feat not duplicated until very recent times—and some of the measurements are still the best available.

With the passing of the age of sail, interest in ocean currents declined for a number of years. The sinking of the steamship *Titanic* in 1912 provided new impetus for the observation of currents, because of their importance in transporting icebergs into the North Atlantic shipping lanes. These observations have been continued by the U.S. Coast Guard to the present. In such studies, average currents are of little value; week-to-week changes are all important.

BENJAMIN FRANKLIN'S MAP OF THE GULF STREAM
LAND of the ESKIMAUX's or LABRADOR
ATLANTIC OCEAN
NEW ENGLAND
NOVA SCOTIA
Newfoundland
NEW YORK
PENNSYLVANIA
VIRGINIA
NORTH CAROLINA
SOUTH CAROLINA
GEORGIA
WEST FLORIDA
GULF of MEXICO
A CHART of The GULF STREAM

NOAA

Ben Franklin had this map of the Gulf Stream prepared when he was Postmaster General.

Recent Analysis of Ocean Currents

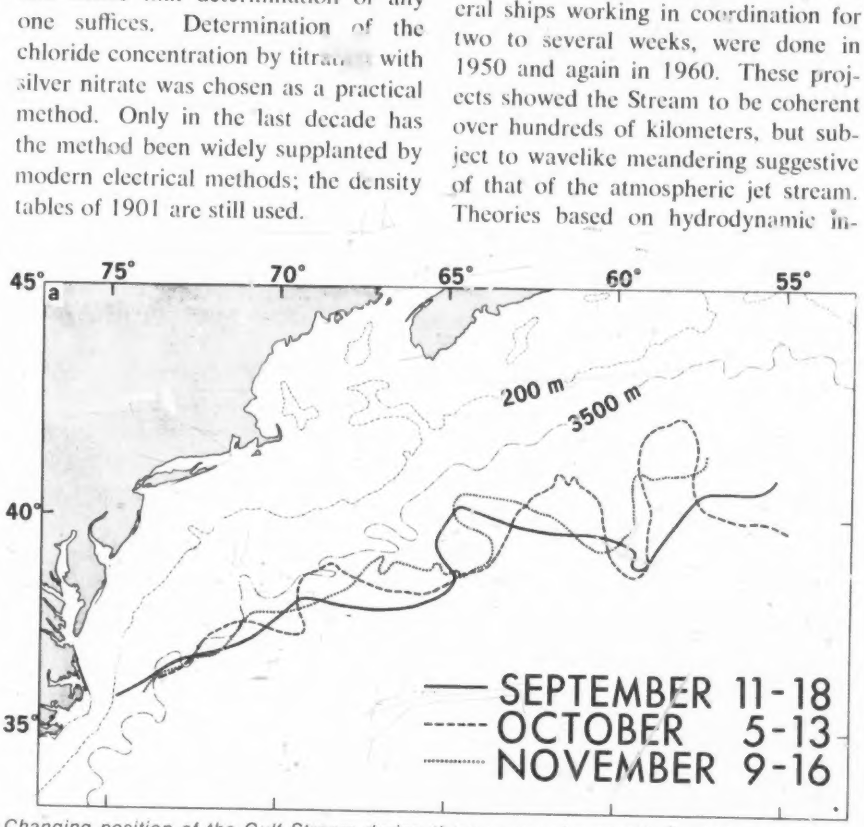
The ice patrol work was made possible by development of a new technique—the geostrophic method—similar in principle to that by which winds are inferred from pressure patterns on a weather map. In application to the ocean, pressure cannot be directly measured, however. Instead, advantage is taken of the fact (not always true) that the surface currents are much more vigorous than the deeper waters, and the relative pressure is determined by integration of the density variations over the water column.

In the standard-temperature-and-pressure laboratory world we usually get by considering water as incompressible. Throughout the ocean, the density of water varies by approximately 7.5 percent, of which 5 percent is due to compression. The remaining 2.5 percent, the important part, is due to variation of temperature and salinity. To detect the variations of importance required development of special thermometers, special chemical methods, and special glassware.

The chemical method was based on the results of the British *Challenger* expedition of 1872-6 which showed that the major ionic species dissolved in seawater occur in almost constant ratio and hence that determination of any one suffices. Determination of the chloride concentration by titration with silver nitrate was chosen as a practical method. Only in the last decade has the method been widely supplanted by modern electrical methods; the density tables of 1901 are still used.

This method was applied in scientific investigations of the Gulf Stream soon following establishment of the Woods Hole Oceanographic Institution in 1931. The major goal was to monitor Gulf Stream transports as they might affect fisheries and climate in the North Atlantic and western Europe. To obtain sufficient measurements for a detailed description of the Gulf Stream was both tedious and expensive. The basic transport (of water) of the Stream could, however, be inferred from vertical soundings at just two stations. It was hoped to define standard stations that could be monitored for correlation with other events of interest. Because of confusing variations and indications of multiple streams, it was not possible to define the standard stations before the program was interrupted by World War II.

Following the war, scientific oceanographic research was pursued much more vigorously, particularly at the major centers such as Woods Hole. Synoptic surveys, accomplished by several ships working in coordination for two to several weeks, were done in 1950 and again in 1960. These projects showed the Stream to be coherent over hundreds of kilometers, but subject to wavelike meandering suggestive of that of the atmospheric jet stream. Theories based on hydrodynamic in-



Changing position of the Gulf Stream during three successive months in 1965. The lines show the month-by-month position of the core of the stream along the coast.

stability, in which perturbations are able to extract energy from the basic current, or on effects of bottom topography, were advanced to explain this behavior; but the observations of Stream paths were too few to permit firm conclusions. A recent series of Stream path observations at monthly intervals by ESSA vessels[1] has shown that none of the present theories satisfactorily explains all features of the observations.

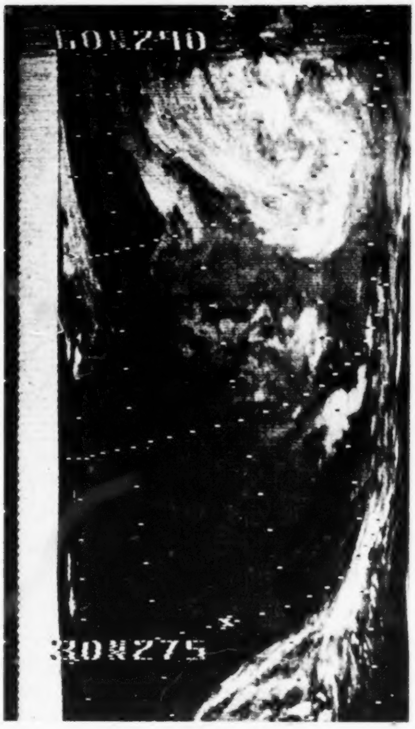
It appears that we do have a satisfactory explanation for the basic existence of the Gulf Stream. Details are still being debated, but the essential ingredients are the winds, which drive surface waters southward and westward over most of the North Atlantic; and the sphericity and rotation of the earth, which force a narrow return current on the western boundary of the ocean. Similar logic applied to the deeper waters (but with the flow driven by sinking of water in high latitudes and upward movement of deep water almost everywhere else) suggests that the deep circulation should be the exact opposite of that at the surface—its speed should be about 1 cm/sec; and it should be complete with a deep, opposite, counterpart to the Gulf Stream. It is now clear that this countercurrent exists, but attempts to demonstrate the existence of the general northward flow elsewhere have been thwarted by the discovery of variable currents on the order of 10 cm/sec which obscure the average flow. Because the effect of these transient currents on the average flow is unknown, it now appears that our understanding of ocean circulation may be as poor a representation of reality as the Hadley cell was of actual atmospheric winds.

One of the major problems in advancing knowledge of ocean currents has been the difficulty of obtaining useful measurements. Current patterns can change too rapidly for a single ship to define more than their grossest features, and investigations involving several ships are expensive and difficult to organize. In the coming decade, however, there is the real possibility of observing oceanographic parameters related to ocean currents using satellite-mounted sensors. These sensors would provide observations of entire ocean basins in short times. Considerable work is being done at present on observations of sea surface temperatures using infrared sensors, but development of very precise satellite altimeters for observing variations of sea level can bring about a genuine revolution in observation of ocean currents by providing at last the badly needed measurement of absolute pressure gradient.

The Coastal Zone

In the preceding pages, I have described developments in knowledge of the deep sea. By most measures other than national defense, however, the interest and emphasis of the nation, individually and collectively, will probably focus on what is described as the coastal zone. This zone is broadly defined as extending from the edge of the continental shelf, across the coastline, into the estuaries and the Great Lakes, and the land area affected by proximity to the ocean or the Great Lakes.

We are all aware of the growth of population generally. It is perhaps less well known to what extent this growth is occurring primarily in the coastal zone. Between 1860 and 1960 the fraction of the U.S. population living in counties bordering the sea or the Great Lakes increased from 25 percent to 45 percent. This is the region where man and the sea interact; and the interaction is becoming increasingly a two-sided proposition, as extensive modification becomes technologically possible. This is also the region where all marine economic activities have their greatest concentration, now and for the foreseeable future.



NOAA

Infrared view of eastern U.S. was obtained in September 1966 by the research satellite Nimbus II. *In processing, the usual arrangement of infrared photographs in which the warmest areas are the lightest has been reversed, so that the warm waters of the Great Lakes appear dark and the cold ice-crystal cirrus clouds over Florida (lower right) are light.*

Traditionally, we have treated this margin of the sea, like other waterways, as property held in common, to be used by all according to their needs or desires. With mounting population and economic pressures, this leads to a destructive procedure in which each sees a net personal gain in his personal contribution to overuse. Hence, this zone will be the scene not only of increasing activities and benefits during the 1970s, but also of increasing conflict and controversy. The general nature and importance of the biology and ecology of the region is currently receiving considerable exposure. For all these reasons, President Nixon in 1969 announced increased emphasis on the coastal zone as one of the major national programs in oceanography for the coming decade. By personal orientation and because the pressure is greatest there, I will focus primarily on physical behavior of estuaries.

Estuaries

Originally the term estuary was used in reference to tidal portions of rivers, but usage has been broadened generally to include any semi-enclosed body of water having more or less free exchange

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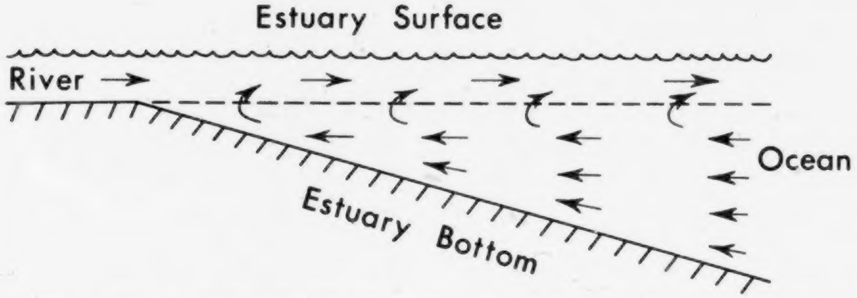
[1] The National Oceanic and Atmospheric Administration (NOAA) was created by President Nixon on October 3, 1970, by Executive Order and assigned to the Department of Commerce. The reorganization consolidated the efforts of 23 separate departments and agencies of government. Among these were: the Environmental Science Services Administration (ESSA); the Bureau of Commercial Fisheries; Marine Game Fish Research Program; Marine Minerals Technology Center; National Oceanographic Data Center; National Oceanographic Instrumentation Center; and the National Sea Grant Program.



Schematic illustration of estuarine circulation. In its most basic form, this consists of seaward flow of fresh or brackish water near the surface and landward flow of salt or brackish water near the bottom, with turbulent mixing between the layers.

with the ocean and in which ocean water is generally diluted by fresh water from rivers or other upland drainage. Extensive occurrence of estuarine areas, such as we have at present, appears to be an ephemeral state in geologic time, existing briefly following a change in sea level. The profusion of estuarine areas on our Gulf Coast, for example, is estimated to be only five to six thousand years old; it can be expected to last another four thousand years if the sea holds its present level and man does not interfere.

There are several reasons for the short life of estuaries. The most obvious is upland sediments deposited in the estuary by rivers and streams. More important, however, are reasons associated with the circulation of water. The estuary is a transition zone between fresh water of the river and saltwater of the sea. Because of its salt content, surface seawater is about 2.5 percent more dense than is fresh water. This density difference gives rise to a system of convection currents which is so common in estuaries as to be termed "estuarine circulation." In its most basic form, estuarine circulation consists of seaward flow of fresh or brackish water near the surface and landward flow of salt or brackish water near the bottom of the estuary, with turbulent mixing between the opposing layers. The landward flow near the bottom carries oceanic sediments into the estuary and impedes the movement of upland sediment through the estuary, thus forming a self-destroying trap for sediments from both sources.

Also, since deeper ocean waters tend to be more fertile than are surface ocean waters, both the landward flow and the river flow tend to enrich the estuarine water, leading to much greater biological production than in the open sea and, hence, to much more rapid biological sedimentation.

On a much shorter time scale, this circulation pattern is of importance to the interests of man. It is a primary reason why Puget Sound is nearly as cold in the summer as in the winter. It is of obvious relevance to efficient disposal of wastes. The value of estuaries and wetlands as nursery areas for oceanic species is being well publicized; the larvae of these species have poor motility and ride this circulation system into the nursery areas. It is clear that knowledge of the dependence of the salinity stratification and circulation should be well established before the modifications that have been and will be made are begun. The general principles are in fact reasonably well known. The basic controlling features are geomorphology (primarily depth), volume of freshwater flow, and tidal regime of the estuary. An increase of depth, tidal current, or river flow can generally be expected to increase the circulation. It is difficult to give quantitative estimates, however, because the flow is turbulent, and turbulent processes have proved extraordinarily difficult to handle in all fields of science and engineering.

There are other very interesting variations on this basic pattern. It has been shown, for example, that because there is relatively little fresh water flowing into the Baltimore harbor, exchange of water between the harbor and the larger Chesapeake Bay is three-layered: inward at surface and bottom, outward at mid-depth. Although this flow is weak, it provides flushing of the harbor five times as rapid as is estimated by standard engineering rules. In still other inlets, flushing takes place seasonally as water of different density, usually because of varying river flow, occurs at the entrance. Such a mechanism can be expected to be severely disturbed by river flow diversion or equalization projects.

There is also a growing body of evidence that these same general considerations apply in regard to movement of water between estuaries and open sea areas offshore, which is of quite obvious importance in regard to offshore waste disposal operations.

Goals for Science Teaching

In conclusion, I wish to state three somewhat philosophical suggestions for science teaching as it touches on oceanography or, more generally, environmental problems. My thoughts here are strongly conditioned by a personal conviction that education for responsible citizenship is a higher goal than education for careers in science.

First, there is the necessity to impart to students the realization that value judgments must and will be made, consciously or unconsciously. Secondly, since the first law of thermodynamics is indeed irrevocable, students must be made cognizant of potential hidden costs in technological bargains.

Finally, students must be shown that it is science properly understood and used that gives us essential options. It is not until faced with really hard choices, like resolution of the thermal pollution problem, that we realize just how much research is still needed, particularly in environmental matters. Then we suddenly discover a great need to narrow the range of expert opinion on the effect of elevated temperature on biota and long for better knowledge of seasonal temperature and circulation patterns and more complex ecological puzzles in natural waterways. In the coming decade, it appears that these needs for environmental research can only become more acute. □

Can Our Conspicuous Consumption of Natural Resources Be Cyclic?[1]

LEALLYN B. CLAPP

Professor of Chemistry
Brown University
Providence, Rhode Island

SINCE a natural resource is never consumed (except for the sun's energy), the answer to the title question has to be yes. Exhaustion of the sun's energy will not be a real limitation for a billion years.

By conspicuous consumption I mean the profligate American use of about 19 tons (per person) of the world's resources each year, compared to 2 tons for everybody else.[2] In 1950 each American was using 18 tons of the world's resources divided into those categories shown in Table 1.

This imbalance in our use of natural resources is recognized by citizens of the world and often resented but seems to be taken as a natural right by unquestioning Americans. The resentment against the imbalance is compounded because the difference between our supply and our demand is made up (in several cases) by importation of other people's resources. To be sure, we pay for the resources with food, tourists, plastics, and pens that write under water, but these are replaceable while the importations (fuels and ores) are irreplaceable resources. Resentment against the Ugly American might be in part relieved if we tried to change these imbalances.

Two ways to do this suggest themselves. We could continue and extend our help to other people in developing their own resources (e.g., by peaceful uses of atomic energy); and we could try to make our own consumption cyclic.

Chemists hold that a natural resource is never consumed[3] but only converted into new forms; e.g., a metal into an oxide (iron rust), fuel into carbon dioxide and water, falling fresh water into a reservoir of seawater, fertilizer into protein, etc. The chemist sees the problem of excessive consumption as one of converting the end product back to resource so that, in fact, there is no "end product" but only a cyclic process. Since any or all the steps in the cycle may consume energy, the bottleneck in excessive consumption of natural resources is, in the end, energy. In the final analysis, the source is the sun's energy, and this is nearly an infinite resource.

Table 1. Per person use of resources in the United States (in tons)

RESOURCE	1950	1969[a]
Fuel	7.2	7.5
Building materials	5.4	5.8
Agricultural supplies	2.1	2.3
Metallic ores	2.55	2.65
Food	0.75	0.75
	18.00	19.00

[a] Extrapolated

To make any resource cyclic, the first requisite is a large supply of the original resource, since a cycle may not be completed for years or even centuries. At present the use of only five resources, nitrogen [3], iron, copper, lead, and lumber,[4] is in any sense cyclic. (However, we are beginning to worry about air and water, resources not included in the 19 tons.)

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[1] Based on a lecture given at several colleges in the past two years under the auspices of the Visiting Scientist Program of the Division of Chemical Education of the American Chemical Society.

[2] The figure of 19 tons is a 19-year extrapolation of figures available for 1950 from "Resources for Freedom." U.S. President's Materials Policy Commission. U.S. Government Printing Office, Washington, D.C. 1952. Five volumes. The report was neither pessimistic nor optimistic in outlook.

[3] The one exception is the element helium, which is lost to the upper atmosphere irretrievably when it is allowed to escape from balloons or tanks.

Of the five categories making up the 19 tons, fuel, agricultural supplies, and metallic ores are amenable to the present discussion. The problem of building materials is one of transportation, not supply, so that energy remains the main bottleneck. The problem of food, is partly a matter of agricultural supplies (fertilizer).

ENCHANTMENT of the original supply of a resource depends on new discoveries or on the use of slimmer and slimmer reserves of resources. Both sources are available to increase fuel supply. Geologists recognize that oil and gas discoveries even in the United States have surpassed usage by about 3 percent per year since 1920. Slimmer reserves (oil shale in Colorado and Wyoming) are untapped at present but will extend the oil supply 135 years at present consumption rates. Coal reserves (new discoveries are not expected in the United States) will last several centuries (500 years' supply under Utah). The world's supply of oil, gas, and coal will last about 900 years at present rates of use, but only 200 years at rates expected by the year 2000.

After exhaustion of fossil fuels, the combustion products (carbon dioxide and water) may have to be converted back to liquid fuels, first by atomic energy, and finally by the sun's energy. Evidence that carbon dioxide content in the earth's atmosphere is increasing beyond a safe margin may necessitate removal of carbon dioxide from the atmosphere, most happily by recycling it back to a fuel. Alternatively, efficient fuel cells or some new invention may speed the change from present dependence on fossil fuels.

In the field of mineral exploration, the reserves get larger every year, because new discoveries in technology allow use of slimmer and slimmer resources. The two most convincing examples are those of copper and iron.

The first copper ores in Michigan contained about 14 percent copper. The content gradually retreated to 2 percent, and the ores now mined in Arizona and Montana, containing 0.9 percent (even as low as 0.5 percent) copper, are still economic.

A more complete recovery of the metal from its ore also helps to extend the original resource. A recent use of ion exchange in the leach liquors of mine tailings promises a 97 percent recovery of copper from this source. [2]

Iron ores were once economically unrewarding unless they contained at least 30 percent iron. New taconite ores of 15 percent iron are beneficiated and compete with better grade ores from the Mesabi range. Mineral resources ordinarily suffer an orderly retreat to slimmer content as the economic recovery of known resources gradually becomes more expensive.

The story of uranium resources in the past few decades suggests another way in which we have had to change the basis of our thinking about natural resources. [5] In 1945 our uranium reserves were so low that it was classified information to conceal a military weakness. By 1954 the uranium ore reserves were in the millions of tons. Now we have 80 million tons of proven reserves, and the United States government has not been buying uranium ore since 1962.

How did the change come about in such a short time? The search for uranium ores was turned into a national lottery in which the ticket was a Geiger counter, the prospector rode in an airplane and not on a mule, and the prize was a sizable bonus for discovery and production. It was a very popular lottery. The search provided amusement, adventure, and even a serious patriotic purpose; and it worked. Perhaps the method would not work in the case of other metal shortages, however it is in the realm of possibility. Uranium is not a unique case since half the elements in the periodic table are more abundant than is uranium. Though radioactivity could be used to explore for only two other elements, thorium and potassium, other techniques could be used to locate other ores. Color aerial photography could be used, for example, for exploration for other minerals.

WILL AVAILABLE agricultural supplies sustain the world indefinitely? Or each United States citizen at the rate of 2.3 tons of resources per year? The three necessary substances which must be renewed in the soil continually are potash, phosphate rock, and nitrogen (as nitrate or ammonia). The world supply of potash and phosphate rock is on the order of 50 billion tons. At the rate of consumption expected by the year 2000, the supply will still extend for 700 to 1,000 years. Only then will cyclic consumption be necessary. The leaching of these two resources from the soil eventually carries them to the rivers and finally, the ocean. Recovery from the ocean may in the end be a necessity.

The supply of nitrogen is truly inexhaustible since 80 percent of the air is nitrogen gas. Synthetic ammonia, urea, and nitrate have been competing with Chilean nitrate since World War I. The limiting factor in making agricultural supplies undergo cyclic consumption is again energy (and ingenuity). Only recently, better technology cut the cost of ammonia synthesis in half.

TO SUM up, *scarcity* of natural resources in the United States has actually been *decreasing* by ⅓ of 1 percent per year since 1870. [4] Nevertheless, meeting production of metallic ores, to the extent of 2.65 tons per person per year, is fraught with uncertainties because of the importation problem. The United States obtains only two important metals completely from our own sources, magnesium from seawater and molybdenum from Climax, Colorado. Molybdenum is used in steel manufacture, and we have a virtual monopoly of it. The use of other important metals depends more or less on ore importation.

This is especially true of the heavy metals. We import substantial quantities of copper [6], iron, zinc, and lead ores and all the tin that we use. We reached this stage with iron in 1953 when the first iron ore shipments arrived in Philadelphia from Venezuela. In 1969, we are importing 23 percent of our iron ore. By 1975 we will be importing 40 percent of our iron ore—from Venezuela, Labrador, and Liberia. We will soon have to induce foreign countries to double their production of copper, iron, and lead, and almost double zinc output. Among the light metals, we will, by 1975, also need four times as much aluminum and 18 times as much magnesium as we did in 1950. We can supply the magnesium by running more seawater through our plants, but aluminum production will depend on other peoples.

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[4] Conservationists have been very effective in making the lumber supply cyclic in character.

To produce aluminum we need bauxite (an aluminum ore) and cryolite to dissolve the alumina prepared from bauxite. We depend on Jamaica, Surinam, Italy, and Mexico for bauxite. In 1950, we thought there was only a 40-year supply from those four countries. But in 1942 a farmer had discovered a new supply of bauxite in Jamaica, because he wondered why his land was so poor. It took several years to find that he had discovered a 300-year supply. Aluminum production will depend on the willingness of Jamaica to supply our increasing demand for aluminum ore.

If Venezuela decided to keep her iron ore and build her own smelters (or Jamaica decided to keep her bauxite), should we just wave more American dollars to get the iron ore or otherwise make it economically impossible for Venezuela to make an independent decision?

Could we make our consumption of metallic ores more nearly cyclic by solving the problems of scrap metal recovery? [1] I shall examine the metals separately since the scrap problems are different for each one. To begin we need to reduce this 2.65 tons of metallic ores to poundage of the metals themselves. Smelting and refining reduces this figure to those given in Table 2.

Table 2. Metal and mineral equivalents (pounds) extracted per 2.65 tons of ore

Iron	1400
Phosphate	150
Aluminum	98
Manganese	36
Potassium	24
Copper	15
Zinc	15
Lead	8
Calcium fluoride	7.4
Sulphur	0.72
Molybdenum	0.33
Gold	0.008

Shouldn't we attempt to make our steel consumption cyclic by using more scrap iron? How well is the job being done now? Most of the scrap from the steel mills and fabricators gets back into circulation, but of the 72 million tons used for containers, transportation, construction, and durable goods about one-fourth is recovered, one-half goes into a 26.5-year recovery cycle, and one-fourth is considered nonrecoverable. We do a poor job of collecting junk and getting it back as metal into cyclic consumption. Only about 25 percent of scrap iron gets back into circulation.

The aluminum industry is not old enough to have formed a large scrap industry. Two-thirds of all the aluminum ever used was made in the last 10 years, and the 30-year cycle of recovery is not nearly complete. Most of the aluminum is used in the airplane industry, and the scrap problem has not been faced.

Copper gets back into the stream of usefulness more completely than does any other metal—about 75 percent is recycled over a 35-year period. This is because copper is easily identified. It is red, and much of it is in the form of wire. Three percent of copper now in use is recovered annually.

Lead scrap, nearly 500,000 tons per year, comes largely from storage batteries. Lead is the most easily recycled metal, for melting and recasting are all that is necessary. Collection is also easy, for batteries are not conveniently ignored and are commonly left at the point of exchange. The fixed-use period (three years) also makes recovery steady and predictable. Each battery contains 25 pounds of lead. At present 50 to 60 percent of the lead in use is recycled.

Are natural resources ever consumed? No, but we can prolong the cycle of recovery, and the entropy of our natural resources can increase so that it takes energy to gather them together again. We do such a good job of scattering our metals that someday we may have to lengthen the 30-hour week back to 40 hours and spend the 10 hours gathering scrap metal.

In conclusion, the total resources of the world might be enough for three times its present population but not at the American rate of consumption and not with our present attitude toward cyclic recovery.

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Suggested Reading

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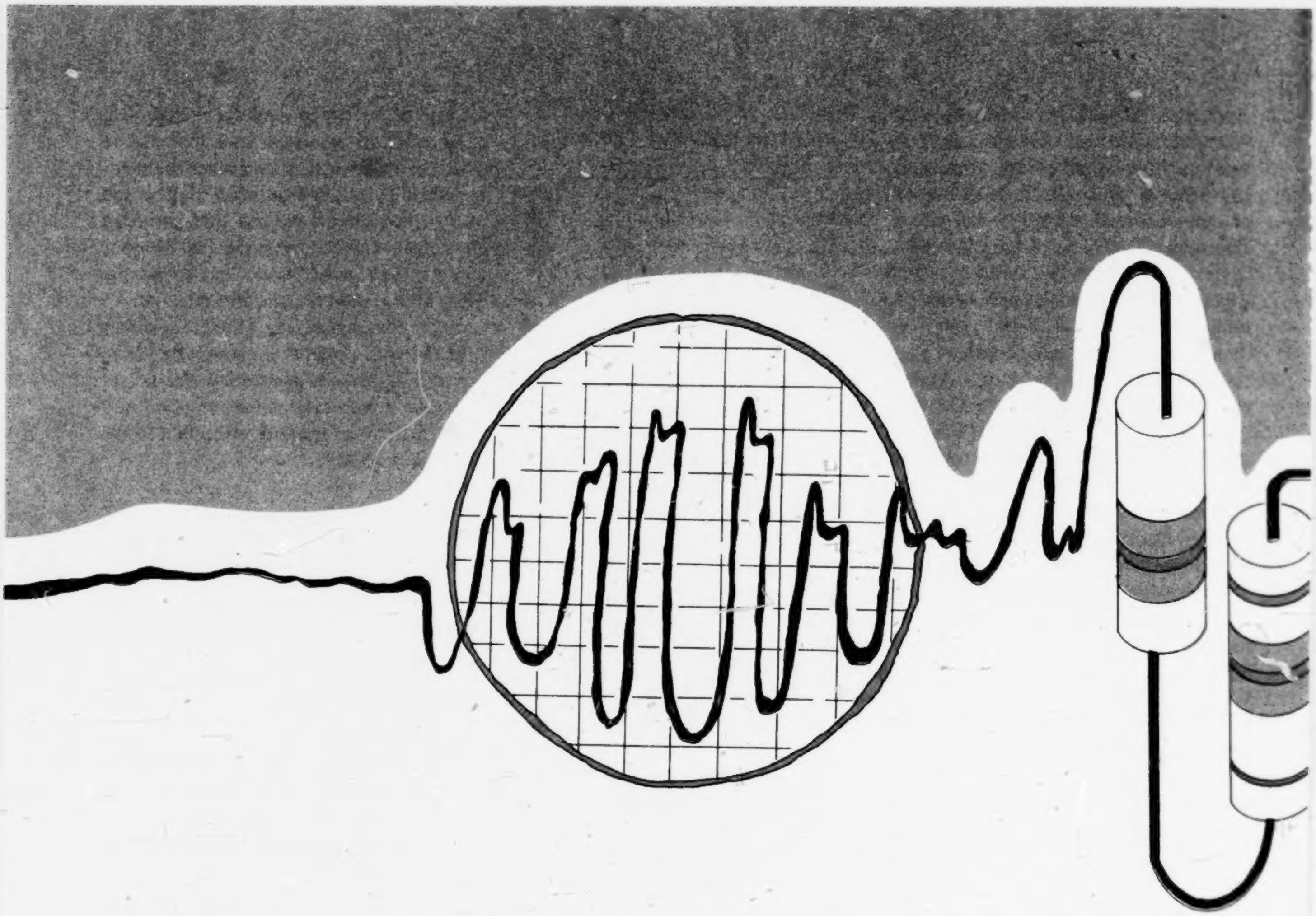


TECHNOLOGY assessment is a type of analysis which attempts to identify both the long-term benefits and the long-term costs to society resulting from the introduction of a new technology. The reasons for the recent interest in this type of analysis are obvious. Virtually all of the nations of the world whose agricultural or industrial technology is advanced realize that the utilization of technological advance for immediately obvious benefits often results in long-term costs, most strikingly evident in the degradation of the environment or ecology. The sum total of these costs, if known to society when the decision was made to introduce a new technology, might very well have resulted in a "no go" rather than a "go" decision—or at least such information might have stimulated an examination of alternate ways to achieve the desired benefits.

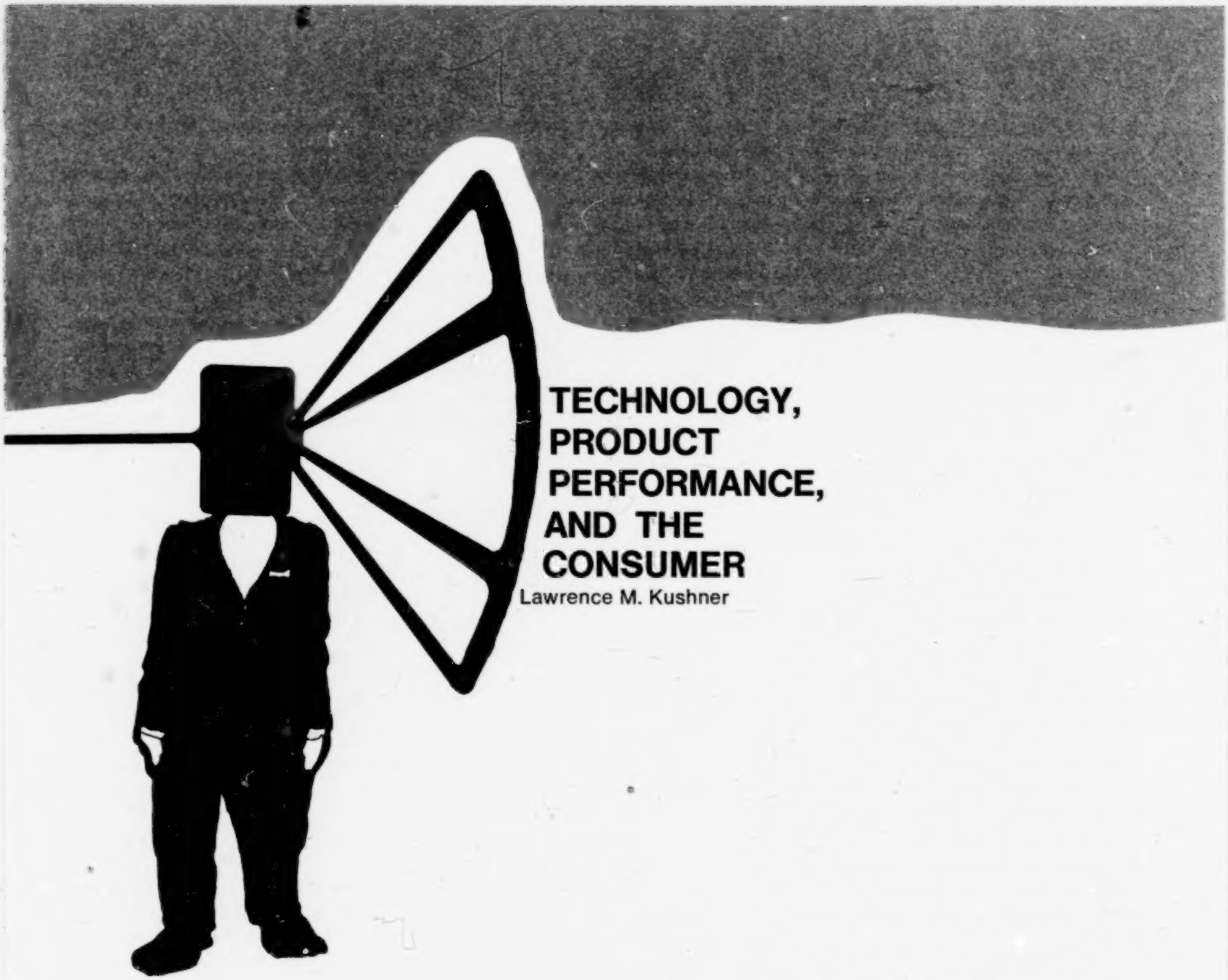
Dr. Kushner is deputy director of the National Bureau of Standards, U.S. Department of Commerce. This paper was his part of an NSTA-Sunoco Science Seminar at the 1971 Convention of the National Science Teachers Association in Washington, D.C., on March 28.

In the last Congress, environmentalists and proponents of continued technological development alike, made first steps toward defining a technology assessment mechanism to guide the nation in policy-making. In Section 102 of the National Environmental Policy Act of 1969, all government agencies are required to report to the Council on Environmental Quality on the environmental impact of proposed actions and programs. These reports deal with such diverse proposals as those described below:

A small city plan to expand its bus fleet (with federal aid), where the environmental impact may be to alter the concentration of air pollutants, or to require the long-term commitment of previously unused land for a bus garage, or to adversely affect a regional transportation plan designed to minimize the construction of freeways, etc.

A plan by the Army Corps of Engineers to dredge a three-mile channel in Bayou Coden, Alabama, to give shrimp and oyster boats better access to docking facilities in the village of Coden (population 500). Here the considerations are the effect on fish and wildlife of the Bayou and potential damage to some thirty acres of wetlands, as balanced by the expected economic gain to the locality.

At the other extreme is the Trans-Alaska pipeline proposal, a plan to construct and operate a four-foot pipeline carrying hot oil



TECHNOLOGY, PRODUCT PERFORMANCE, AND THE CONSUMER

Lawrence M. Kushner

over an 800-mile course southward from the northern oil fields of Alaska. The proposed line would deliver two million barrels of oil a day at the southern terminal at Valdez Bay. It would cross regions of tundra and permafrost, four major river systems, and numerous active seismic zones and would pose obvious problems if a break or leakage should occur. In addition, a major analysis of the potential ecological effects must be made, and the effect of opening up an 800-mile strip to human population growth must be assessed. Rational examination of the plan is demanding serious study by earth scientists, biologists, meteorologists, and a variety of experts in engineering. Active discussion will continue for a long time.

In the same Congress, a House Subcommittee on Research and Development, chaired by then Congressman Emilio Daddario of Connecticut, commissioned studies and reports from both the National Academy of Sciences and the National Academy of Engineering on how the legislative and and executive branches of government can be provided with capabilities which are adequate for technology assessment.

For the purposes of this paper, the organizational alternatives suggested in the reports are not important. What is of interest is the unanimity of opinion regarding the extraordinary complexity of technology assessment analyses and the difficulty of using their results with confidence. The overriding importance of second- and third-order effects integrated over a long period of time and the wide range of interactions between adjacent technologies virtually eliminate the utility of such analyses as predictions of the future. At the same time they highlight the importance of making rational decisions. And decisions will have to be made. Technology will not stand still. Policies which would try to make it do so are not only futile, they are self-destructive. The worldwide population increase—the aspirations of man for food, health, and freedom—require more and new technology, certainly used with more discretion than in the past, but developed and used, nevertheless.

The impact of technology on the consumer, while massive, is also complex. It consists of direct assaults, such as in the technical sophistication of the products he purchases, but it also includes more subtle ones applied in shaping his wants, expectations, and shopping habits.

TECHNOLOGY is defined by Webster as "the totality of the means employed by a society to provide objects necessary for human sustenance and comfort." Note the stress on "means" as opposed to the objects, themselves. The *ways* in which we satisfy our needs are as much a part of our technology as are the artifacts we produce and use. Marshall McLuhan's "message" expands on this point. It is useful to examine the impact of technological progress on the consumer in this broader sense.

A major thesis offered by John Kenneth Galbraith in his book, *The New Industrial State,*[1] is that the traditional version of a free-market economy does not exist in the United States. It is no longer true, he claims, that production responds to the needs of consumers. Instead, major manufacturers such as those of automobiles, because of the massive investments required to market a new product and the competitive necessity of offering new products every few years, cannot wait for nor depend on the operation of a free market. Having committed themselves to market a new product, say a three-dimensional TV set, some two or three years hence, such manufacturers must invest tens of millions of dollars in remarkably effective advertising campaigns to assure that a ready and anxious market awaits the product.

The effectiveness of this advertising is at least as much a product of technological development as is the 3-D TV set, itself. The full power of communications technology is brought to bear to develop consumer wants based on appeals to prestige, image, power, self-gratification, and sex. The issue of need is not normally addressed. The consumer wants what he is led to want. That this can be done so successfully would be inconceivable without our high science-based communications technology.

At least as important, the consumer's expectations regarding the product are shaped by essentially emotional appeals which it is not likely to satisfy. Buying a particular model of automobile is not likely to turn the average secretary into a jet-set swinger. The seeds of consumer frustration are planted early.

The shopping process, itself, has been shaped by technological developments. The automobile, by making possible suburban dispersal, is at the same time bringing about the demise of the downtown, high-concentration business districts in which comparative shopping was easier, and reasonably knowledgeable sales personnel could be found. Instead, one-stop suburban shopping areas offer a limited number of products from which to choose; and sales personnel, although generally willing, are unable to provide authoritative assistance. "Low overhead" marketing technology, in fact, is predicated on a minimum of customer/salesman interaction. By buying "in the carton," the consumer concedes his right to expect any responsibility for the product by the retailer.

The ubiquitous credit card whose very ubiquitousness is a direct result of computer technology applies the "coup de grace" by making the consumer so susceptible to impulse-buying that he buys what he doesn't need—and perhaps can't afford—while paying a surcharge for doing so.

Finally, one comes to the technology embodied in the product, itself. There is no doubt that the technical sophistication and, in most cases, performance far exceeds one's reasonable expectations a generation ago. The contention that we no longer make things as we used to is absolutely correct. Today, products are far better. The modern "home entertainment center"—AM/FM radio and color TV, phonograph, tape deck—is a marvel of technical sophistication and performance. And the most sophisticated of its subsystems—its electronics—is remarkably trouble-free since the introduction of solid-state electronics and integrated circuits. Today's automobile, notwithstanding its monstrous effect on society, is a vastly improved product over what it was years ago. The improvements in ride, comfort, visibility, power, efficiency—and even safety—have not been trivial. This is not to say, however, that owning an automobile is not a much more frustrating experience today than years ago. We shall return to this point.

On the other hand, that product which most of us aspire to—a good home at a reasonable price—is rapidly disappearing because neither the technology inherent in the structure, itself, nor in its production process reflects the technological improvements which are possible with today's state-of-the-art. The reasons for this are complex; but the point is that unless products continue to reflect new technology either in themselves or in their manufacturing process, they soon become unsatisfactory in terms of absolute performance or performance/unit cost.

THE RESPONSE by government to the increasing articulation of consumer discontent has been the creation, at all levels from city to federal, of consumer protection or consumer affairs agencies. This signifies the political appeal of the problem.

Notwithstanding the heroic efforts of some very talented and dedicated people in these offices (whose powers are limited to persuasion and to exposure of improper practices) their impact is slight, and there is a strong push for legislation to put the government in the business of setting standards for products. Such standards would go far beyond the traditional areas of governmental concern—health and safety—and deal with product quality and performance. With due respect for the virtue of the motives underlying such legislation, the potential for harm from the heavy hand of bureaucracy on the traditionally fast-moving and innovative consumer market limits the support for such a drastic program.

Responding to this challenge, the voluntary standardization apparatus in the United States is undergoing intensive self-examination and some reconstruction to deal with standards for consumer products. There are more than 300 trade, industry, and professional associations in the United States which generate voluntary standards reflecting agreements on the design, durability, quality, and other aspects of the performance of products.

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[1] Houghton Mifflin Company, Boston, Mass. 1967.

The problem is that these are for the most part industrial products, and the agreements reflected in the standards are reached between industrial buyers and sellers. Both groups are generally technically competent and strongly motivated by economic factors to reach a compromise which only rarely reflects any explicit consideration of the ultimate consumer.

THE American National Standards Institute (ANSI), this country's national standardization body, attempts to coordinate the activities of these more than 300 organizations. It issues such standards as are developed under the so-called "consensus" principle as American National Standards—still voluntary but meriting recognition as having been developed under procedures which give all interested parties the opportunity to participate in their development.

The "consensus" principle means that manufacturers, distributors (wholesale and retail), and consumers are involved; but one doesn't need to be very perceptive to realize that unless the consumer is represented by highly motivated, technically competent people—the equal of those representing the other parties—he will get short shrift. Strong consumer organizations are needed to get technically competent consumer representation into the standardization process and to get appropriate standards-developing bodies into the consumer product field. Very few consumer product standards exist, even dealing with safety, much less other attributes.

The issue of consumer product safety highlights questions of economic trade-offs and consumer behavior. Since the turn of the twentieth century, there have been many laws which regulate consumer products out of a concern for the safety of the public. First came the Food and Drug Acts, and more recently, the National Traffic and Motor Vehicle Safety Act of 1966 and the Flammable Fabrics Act Amendments of 1967. Under these Acts the Department of Transportation issues mandatory safety standards for automobiles, and the Department of Commerce, for the flammability of wearing apparel and interior furnishings.

In many cases, the introduction of a standard imposes additional costs on the manufacturer which are ultimately passed on to the consumer. How much safety does the consumer want and at what cost and/or inconvenience? The consumer pays for seat belts in automobiles and then sits on them. Individuals and society as a whole seem to find some levels of risk acceptable. As our roads have improved over the years, we could easily have reduced auto injuries and fatalities by simply keeping the speed limit constant; but, of course, speed limits continue to increase, signifying that there is some level of risk to which we have unconsciously become adjusted.

Manufacturers of farm machinery, puzzled by their lack of success in reducing accidents by successive improvements in the safety features of their products, learned that as the safety of their machines increased, the riskier became the ways in which they were used. As tractors became less tippable, they were used on steeper hillside. This is an important field of study for social psychologists and behavioral scientists. We need to know much more than we do now about these problems before we can effectively legislate for consumer product safety, no less, product quality.

IN PRINCIPLE, the answer to the product-quality issue is simply to let the consumer know what he is getting in a particular product so that he can make any compromises or trade-offs he is inclined to in selecting among competing products. For instance, if all electric steam irons at time of purchase had tags on them which specified the power consumption, weight, temperature of the sole plate, amount of steam produced between refills, expected lifetime of the handle, corrosion resistance of the sole plate, etc., the consumer would have an intelligent basis for choosing among items.

Of course, in order for such information to be useful, there must be some assurance that the criteria identified (i.e., weight, temperature, etc.) are relevant to the performance of the product, that proper test methods for evaluating each of these attributes are used, and that all manufacturers use the same test method.

This suggests that it may not be standards for products which are needed, but rather standards for the information which should be provided with the product at the time of sale. But even this provides no guarantee of rational judgment by the consumer.

A voluntary program along these lines in the United Kingdom has not elicited the kind of enthusiastic response from consumers one might have expected, and a recent limited experimental program in a major chain of department stores in the Midwest appears to have had similar modest impact on the consumer. Additional experiments, embodying new ways of providing the information and measuring the impact, are needed.

IF WE return to the automobile case as typifying the impact of technology on the consumer through the products he buys, the locus of discontent emerges clearly. It is the difficulty of obtaining satisfactory service as it may be required. Quite frequently the product is delivered defective. More often difficulties develop as the product ages. In the former case, the problem for the consumer is inadequate procedures for honoring the explicit or implied guarantee. In the latter case, one is concerned with simply one instance of an endemic problem in the U.S. today—the inefficiency of many of our service industries.

It is likely that the consumer is being hurt economically much less by the high technological content of the products he buys than by the *low* technological content of the services he purchases. In this connection, we return to the definition of technology which stresses the ways in which we meet our needs as well as the hardware, itself. The organization and management of our railroads are at least as important components of that industry's technology as its inventory of tracks, cars, and stations.

In the service industries, we see

some remarkable contrasts that show clearly that the public is best served where technology keeps advancing, albeit under the effective management of those who understand it. Our telephone service in the United States is unparalleled anywhere in the world. It is the most technologically sophisticated civil industry we have. It is not only skillful in exploiting scientific advances for useful technological developments; the industry has actually forced scientific advance in some fields.

The telephone industry did not wait passively for solid state devices to come along and then use them. The industry force-fed the relevant areas of science to assure that solid state devices would be available when they were needed. The public is served well by this industry whose management, not coincidentally, consists almost completely of people with science or engineering backgrounds.

On the other hand, the medical service "industry" is plagued by poor service, runaway costs, and the resulting clamor for "something to be done." There are other important problems facing the health-care industry, such as the underproduction of physicians, but the inadequate application of even presently available technology is surely one of its most important. The effective use of new technological developments is the answer to improving the productivity of the industry, thereby making satisfactory care available at reasonable prices.

For instance, medical record-keeping in our hospitals is estimated at about $4 billion per year. Our computer experts at the National Bureau of Standards estimate that the proper use of computers and information handling techniques, within the currently available state-of-the-art, could probably cut this in half.

Of course, more physicians are also needed, particularly to make personal medical attention more uniformly available throughout the country; but even modest increases in the productivity of present physicians and other health-care specialists would have a much greater impact, and in a shorter time, than one can hope for from any likely increase in the rate at which such professionals can be produced in the near future.

Returning once again to the automobile, which epitomizes technological impact on the average citizen, both as a curse and as a blessing, the lack of innovative technology in the service side of the industry is striking. The principal institution through which service is provided remains the individually operated service station or automotive repair shop. Even the service operations offered by franchised new car dealers are essentially cottage industry in contrast with the sophistication of the technology of manufacturing, delivering, and marketing new cars. Gas stations use essentially the same equipment today that they did 30 to 40 years ago. Putting gas and oil into automobiles is identical to what it was two generations ago. As a result, productivity is low, and prices and discontent are high.

One might be tempted to conclude that the way to improve the service "industries" is through bigness—the efficiency of large organizations. Surely, size alone isn't the answer—witness the railroads and the postal service. On the other hand, we note the change in car washing technology—the minute car-wash—which has occurred in a small business but keeps the price of a car wash competitive with what it was 10 or 15 years ago.

THE general public tends to think of technology only in terms of hardware, but a society's software is at least as important. Its analysis of its problems, the way it organizes to meet them, and the way it accomplishes its objectives also reflect its technological sophistication.

One way of characterizing many of our current problems is that the technology reflected in our hardware has outstripped that reflected in our software. Our social institutions no longer appear to be adequate to meet the needs. New social technology is required to regenerate our educational system, to deal effectively with the maintenance of law and justice, and to bring our minorities into the mainstream. Unfortunately, we have no mechanisms for generating this new technology which are as efficient as those we have used successfully in developing the hardware for our society. We must learn what research and development mean in the context of social technology.

The U.S. consumer—or, if you will, the public—is going to have to continue to live with rapidly developing technology. This is not because technology is a heartless, irresistible, self-fueled juggernaut. The high wages and standard of living of U.S. workers as compared to those of their counterparts elsewhere mean that U.S. products can continue to be competitive in world markets only if they are continually being improved and the productivity of U.S. industry is continuously upgraded. Both mean new technology. The long-term economic health of the country depends on our technological prowess. It is essential that the public understands this. Without economic health, satisfactory resolution of our pressing social issues becomes much less likely.

AT THIS time in the human condition, perhaps the most dramatic result of man's venture into space is his new perception of his own planet. This bright and hospitable jewel, floating in a dark and endless void, is seen as a limited and not a limitless resource. Fortunately, this perception emerges at precisely the instant in history that man's impact on the natural ecological processes which have kept the planet conducive to his development are no longer trivial. From here on it will take all of our scientific skill and technological ingenuity to manage intelligently the spaceship, Earth.

If there is an appropriate message to impart to science teachers today, it would appear to be to help the younger generation understand the true nature of technology—its pervasiveness, drama, and subtlety. For right or wrong, technology has helped "turn off" our young people. Perhaps a recognition of its challenge and opportunity can help them "turn on" again. □

energy, technology, and the story of man

Melvin Kranzberg

THE physicists have defined energy as the ability to do work, and they have postulated thermodynamic laws relating different forms of energy to one another and to work performed. But energy is more than a physical phenomenon: It is a social phenomenon. The way in which energy is produced, controlled, and applied—used and misused—helps determine the nature of society. Or, as Fred Cottrell, the sociologist, stated, "The energy available to man limits what he *can* do and influences what he *will* do."[1] Certainly man's material civilization—and much of his cultural life—is dependent upon a technological base, which in turn rests upon man's use of energy. As man has learned to control and apply energy in different ways, society has undergone concomitant changes.

Our prehuman forebears might never have evolved into our present species had it not been for their ability to control energy in the form of fire. During the many climatic changes which occurred during the eons of geologic time, prehistoric men might not have survived without fire to keep warm. It is not surprising that fire was regarded as sacred—a gift from the gods, or, as Greek legend had it, a theft from the gods by Prometheus.

Fire also improved man's chances for survival by increasing his food supply. By enabling him to live in colder areas, fire enlarged the territorial range of man's food-gathering activities. It also made possible cooking, allowing unpalatable or indigestible foodstuffs to be converted into assimilable human energy.

Fire extended man's use of materials. Early man already used stone implements and tools, but the development of pyrometallurgy, enabling him to use the store of metals locked in the earth, greatly extended his power and skills. Copper, bronze, and, later, iron provided man with materials which he could utilize to control and subdue nature, as well as his neighbor.

Yet even with the application of fire, the greater part of energy available to man for performing work came mainly from his own strength. There were two ways by which man could augment his muscle power. One was by domesticating animals, so that they would perform work for him; the other was by devising tools and implements which would amplify and extend the power of his muscles. An increase in energy through the domestication of animals, about the seventh millennium BC, could not make itself felt until more efficient use could be made of animal muscle power by the invention of the wheel (about 2500 BC) and, much later, of a more efficient harness for horses. The increase in power through tools had come much earlier.

ONE of the first "machines" was the bow-and-arrow, which might be viewed as a machine for storing energy and releasing it in directed fashion. When the bowstring is slowly drawn back, human muscle power transmits energy to it; this energy is released suddenly when the archer shoots. The bow-and-arrow and other weapons expanded food supply by enabling man to kill small game at a distance. Other early tools and devices also multiplied human muscle power; this was especially true of the wheel, which made it easier to transport heavy loads over long distances. By classical antiquity, Archimedes could classify the "five simple machines" and analyze the mechanical advantage which they gave man in manipulating things.

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[1] Cottrell, William F. *Energy and Society*. Greenwood Press, Inc., Westport, Conn. 1955. P. 2.

Dr. Kranzberg is head of the Graduate Program in the History of Science and Technology at Case Western Reserve University and editor-in-chief of Technology and Culture.

Even with only rudimentary tools, human muscle power can perform feats of great magnitude if organized effectively. The chief example is the pyramids. Although built before the Egyptians had the wheel, the pyramids demonstrate the prodigious accomplishments of human muscle power when effectively marshalled in the performance of a collective task.

It has been claimed that slavery militated against more effective use of human energy. When faced with a problem requiring the exertion of more force, the ancient engineer simply added more slaves to the work gang instead of devising some ingenious mechanical solution which would lessen the strain on human muscles. Proof of this is adduced from the fact that the water wheel was known in Roman times, but Romans scarcely made use of it. Instead, they continued to rely on human and animal muscle power.

THE Middle Ages witnessed a veritable "power revolution." Rome's decline coincided with the decline of slavery and stimulated the application of new power sources. Water wheels came into widespread use and were improved. The vertical water wheel, introduced in the fourth century after Christ, for instance, had a power capacity of 2 kilowatts, compared with only three-tenths of a kilowatt for the earlier horizontal type.[2] By the time of the Domesday Book (1086), there were some 5,000 mills in England, amounting to one mill to every 400 of the population. First used for grinding grain, water power was later applied to a great diversity of industrial uses, most importantly to drive the bellows of blast furnaces so that the economical process of casting metals could come into widespread use.

Another source of inorganic power contributed to the medieval power revolution: wind. Although wind had been used to drive sailing vessels since antiquity, its use as a power source in the West dates from about the twelfth century. Windmills provided power in flatlands where the fall of streams was too slight for a water mill and where a mill dam would flood too much land.[3]

The medieval power revolution also enlarged animal power by improvement of the harness, which had remained unchanged since about 3000 BC. The old harness had been held in place by a strap around the neck; as soon as the horse exerted a heavy pull, it choked itself. Furthermore, the ancients did not know how to harness horses in file in order to multiply their tractive power; nor did they use horseshoes, and their horses often suffered foot injuries on rough terrain. The rigid horsecollar, probably introduced from Asia during the early Middle Ages, together with horseshoes (ca. the tenth century) and the tandem harness, multiplied the effective pulling power of horses by some three to four times over that in antiquity.[4] A horse driving a machine with the new and more efficient harness was the equivalent of 10 slaves, while a good water wheel or windmill provided the work of up to 100 slaves.

The medieval power revolution, coupled with technological innovations in agriculture and machines, laid foundations for the renewal of town life and the beginnings of industrial technology. The Renaissance saw continued growth in the exploitation of water and wind power as power devices increased in size. By the seventeenth century, the Marly works which pumped water for Versailles had a

ILLUSTRATIONS, LIBRARY OF CONGRESS

Water power was depicted in this engraving of a saw mill and block house on Fort Anne Creek done by Thomas Anburey. (Travels Through the Interior Parts of America, *1789)*

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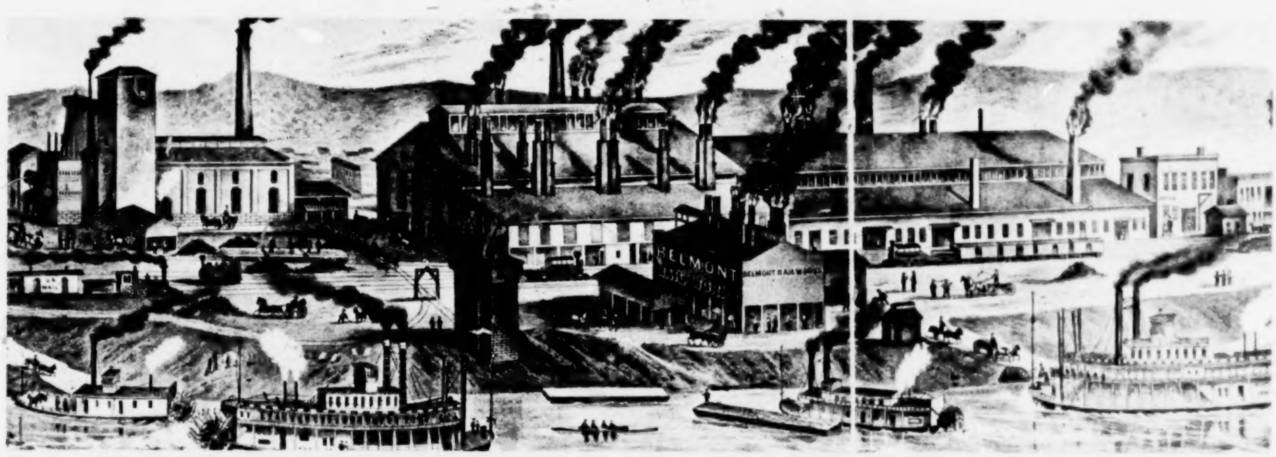
[2] Starr, Chauncey. "Energy and Power." *Scientific American* 225: 37-49; September 1971.

[3] White, Lynn, Jr. "Medieval Roots of Modern Technology." In *Perspectives in Medieval History.* K. F. Drew and F. S. Lear, Editors. University of Chicago Press, Chicago, Illinois. 1963.

[4] White, Lynn, Jr. *Medieval Technology and Social Change.* Oxford University Press, New York. 1962. Pp. 57-69.



Belmont Nail Works, Wheeling, W. Virginia, with Ohio River in foreground. (Illustrated Atlas of the Upper Ohio River, *1877*)

power output of 56 kilowatts; similarly, the capacity of windmills grew from several kilowatts to as much as 12 kilowatts. In addition, the Renaissance developed complex gearing arrangements for the transmission of power from water wheels and windmills so that more efficient use could be made of the energy input.[5]

By the eighteenth century Europe was in desperate need of new power sources. Windmills were effective only in flatlands, such as the Netherlands, where the terrain did not interfere with a steady wind. Water power was intermittent in operation; the flow of water would decline during dry seasons or freeze in cold weather. In England, all the good industrial sites—that is, where there was a sufficient flow and fall of water—were already taken up by factories crowded close together. The need for a new source of power was especially prevalent in the mining areas, to pump water from mines. The steam engine answered that need and became the characteristic power source of the Industrial Revolution.

THE steam engine, and the Industrial Revolution of which it was a part, completely transformed the economic, social, and cultural life of Western Civilization—and ultimately of the entire world. For almost all of human history, the hearth and home had been the center of production, and agriculture had been the chief occupation of the vast bulk of mankind. Men lived in rural areas, their horizons limited, and with a standard of living scarcely above subsistence. Industrialization changed all that. The factory became the center of production; the city became the center of human life and production; family relationships changed, while traditional institutions, such as religion, lost their hold upon men's minds in the new urban surroundings.

A transformation also occurred in the centers of political power. The steam engine gave the industrial advantage to countries with abundant supplies of coal. This advantage was reinforced when steel became the basic industrial material. Because the making of steel required more coal than iron, the location of the energy resource determined the center of steel production. It is not surprising that Britain, with its iron and coal deposits, became the world's industrial leader and the dominant political power during the nineteenth century.

The steam engine was the first mechanical prime mover to provide mobility. Through the steamboat and locomotive, energy from steam revolutionized transportation and brought the world closer together.

Steam both epitomized and embodied the fundamental technological change of the modern era—an incredible jump in available energy. Before the age of steam, the sum total of energy which man could effectively convert to his purposes through wind and water, through animal and human power, was quite limited. Then, in the nineteenth century, man liberated the power of fossil coal through the steam engine on a scale never before possible. The new power, multiplied or divided almost at will, was applied to uncounted tasks.

Yet the steam engine had some disadvantages. It was heavy and cumbersome; almost a century and a half after its development, a reciprocating steam engine could operate at only 23 percent of thermal efficiency. Nevertheless, the power revolution ushered in by the steam engine expanded under the impetus of scientific discovery and technological innovation which created a new prime mover, the internal-combustion engine, and a new form of energy, electricity.

THE internal-combustion engine enlarged, accelerated, and altered the social changes already occurring as a result of steam power. Small, light, and powerful, the internal-combustion engine personalized the amount of power available for each individual, provided transportation for everyone, and made readily available a source of power with which to do a number of tasks, including fulfillment of man's ancient dream of flying. The automobile's effect on American society is so marked as to require no recounting here. The mobility of Amercian society is evident in every facet of our daily life—and this is the result of energy for transportation made available to everyone through the automobile. Furthermore,

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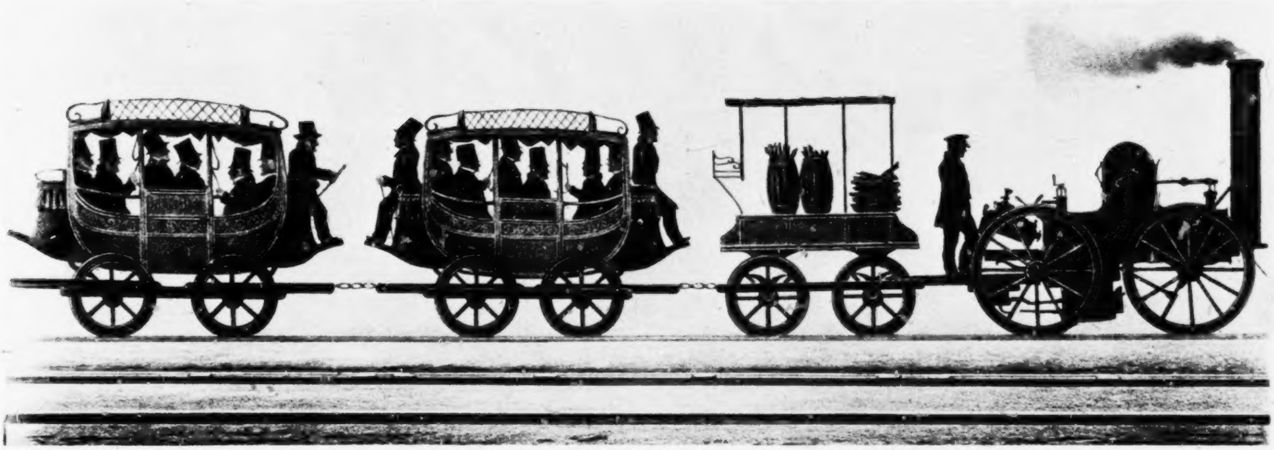
[5] Keller, A. G. *A Theatre of Machines*. The Macmillan Company, New York 1964.



Drawing of the first American railway train as it appeared in July 1832 on the Mohawk and Hudson Railway.

the automobile represents a major factor, perhaps *the* major factor, in the American economy: One out of every eight workingmen in the United States is employed in a task directly connected with the automotive industry.

Equally portentous was the discovery, development, and utilization of electricity. A single comparison with the past illustrates one dramatic change wrought by electricity. One of the romantic episodes of the American West was the Pony Express, begun in 1860, but it was only the ultimate exploitation of a form of communication centuries old—a message carried by a man on a horse. The trip from St. Joseph, Missouri, to San Francisco took ten and a half days—ten fewer than the best stagecoach time. A year later, however, the transcontinental telegraph was completed, and the time for a message to reach the Pacific was again cut, this time to a fraction of a second. Within another 15 years the telephone was a crude though working reality, and the Atlantic Cable shortly after mid-century brought messages across the ocean in an instant. Today, through telecommunications satellites, events occurring halfway across the world are flashed immediately onto television screens in our living rooms.

Electricity has become so much a part of our daily lives that we sometimes fail to recognize how unique and important it is—until a storm or malfunction cuts off our power. We fail also to realize how really new it is in terms of the long time span of human history. Yet it was less than a century ago (1882) that the first electric power station for private consumers, the Pearl Street Station, was established by the Edison Company in New York City. It served a modest load of approximately 1,400 lamps, each taking about 83 watts and constituting an electric demand of 33 kilowatts.

Electrical energy found still another use in the twentieth century. In the census of 1890, the United States Bureau of the Census introduced machines to sort and tabulate data on punched cards, providing the prototype of new means for storing and manipulating information. Previous applications of energy through mechanical devices had lifted the burdens off men's backs. Now the use of energy for information purposes began lifting the burdens off men's minds, freeing them from dull and repetitive tasks.

And, just as the development of earlier energy sources had allowed the exploitation of a wider field of materials, so did the new electronic devices allow for manipulation and exact control of the productive process. Automation reduced the need for human labor while increasing and standardizing output. For the first time in human history, a society of abundance and affluence was possible. The implications of this for work and leisure are still not completely understood.

Contemporaneous with the new applications of energy in the twentieth century—and, indeed, dependent upon them—was a revolution in agriculture. Farm mechanization demonstrates how the application of energy to food production has eased man's toil and, at the same time, increased productivity. As late as half a century ago, approximately one-quarter of the farm acreage in the United States grew crops for feeding the 25 million farm horses and mules; that acreage has been freed to provide food for human beings.

The growing utilization of energy on the American farm has meant that there is less need for human and animal muscle power. Rural workers have been displaced, for they are no longer needed to till the soil; the family farm is fast disappearing, and agro-business is taking its place. A vast migration from rural regions to cities has accompanied the growth of farm productivity, and this has given rise to urban and also racial problems as southern Blacks have migrated to northern industrial centers.

In brief, the manifold applications of energy in production, both industrial and agricultural, have given rise to a new type of society where production, which had occupied so much of man's time and energies over the course of the centuries, no longer presents a problem.[6] The census figures reveal the magnitude of the social changes. What was primarily still a rural and agrarian nation at the beginning of the twentieth century had by the middle of the cen-

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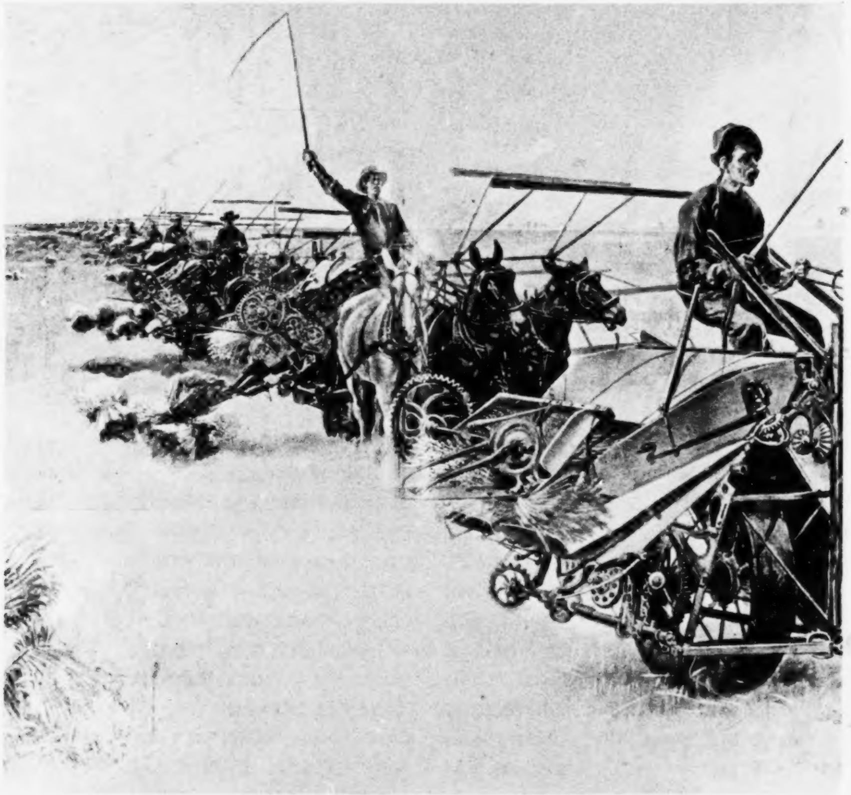
[6] W. W. Rostow calls this "the age of high mass-consumption." In *The Stages of Economic Growth*. Cambridge University Press, Cambridge, England. 1960. Chapter 6.



Harvesting on a bonanza farm. (Harper's Weekly, *August 29, 1891)*

tury become predominantly urban. Late in the 1950s the number of people employed in the service sector of the economy surpassed those engaged in production of goods.

ALTHOUGH ushered in with an act of destruction which still echoes in the conscience of mankind, a new form of energy—nuclear power—marks one of the greatest triumphs of science and technology in our time. Radioactivity had been discovered near the close of the nineteenth century and had caused excitement in a small segment of the scientific community, but the idea of harnessing this energy for useful purposes was imagined only by science fiction writers. In *A World Set Free*, written in 1914, H. G. Wells predicted that nuclear energy would be invented about 1940 and, most presciently, that it would be used in war about 1950. Wells thought that about the middle of the 1950s, the world would come to its senses and realize the possibilities offered by nuclear energy in the form of unlimited, cheap, and ubiquitous energy which would, in a very real sense, set men free from the limitations of previous energy sources.[7]

But something happened on the way to Well's Utopia. Neither man nor energy is yet free. What is worse, the country is confronted with an energy "crisis." On June 4, 1971, the President of the United States sent a message to Congress acknowledging that the country had entered a period of increasing demand for energy and of growing problems of energy supplies. Scientific and technological factors account partially for the energy crisis, but much of the difficulty has arisen from social factors, especially public hostility stemming from fears of thermal pollution and radiation hazards and alarm over danger to the environment from older forms of energy applications.

Americans are demanding a quality environment. They are appalled at ugly strip mines, oil slicks from tanker spills and leaky offshore wells, denuded corridors of land for energy transmission lines, sulfur oxides and fly ash from power plants, noxious emissions from automobile exhausts, and the real or imaginary specter of radioactive perils from nuclear centers. Scientists and technologists engaged in the production and application of energy are thus faced with a major problem: how to protect the environment and still provide for the "good life."

That question poses basic issues about values. The value scheme implicit in our past profligate use of energy was based upon a human history of scarcity—scarcity of material goods to satisfy basic needs of food, clothing, and shelter. Now that we have the potentiality for a sufficiency of material goods, the environmental issue has become of overwhelming importance. Heretofore, American society, with its orientation toward material development, has always considered economic growth as essential to the nation's well-being. Yet if proper cognizance is taken of environmental factors, we might have to slow the pace of economic growth or change its direction.

What message, then, does the story of the development of energy and its impact on man's history have for us? It tells us of the great opportunities offered by human imagination and ingenuity in converting energy to man's use and how such uses inevitably affect our social destiny. With this knowledge in mind, we can face with confidence the current issues involving energy production and application. We can examine our values, we can decide how we want to live, and we can have due regard for the other peoples of the world and for future generations within our own country. We can then arrive at a comprehensive national policy which will take our resources, our science and technology, and our aspirations into account. The present "energy crisis" does not bring man into confrontation with his science and technology; it forces man to confront himself. ☐

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[7] Similar possibilities are set forth in a more recent work by Glenn T. Seaborg and William R. Corliss, *Man and Atom: Shaping a New World Through Nuclear Technology*. E. P. Dutton & Co., Inc., New York. 1971.

ENERGY CONVERSIONS AND ENVIRONMENTAL POLLUTION

Michael D. Henderson
R. Curtis Johnson

THE level of man's technology has increased greatly within the past few decades, with results both spectacularly beneficial and regrettably harmful. The average man in a technological society has a higher standard of living, better state of health, and less arduous way of life in a world of almost limitless conveniences. The cost of these advances has only recently become clear. By-products from man's race to affluence make his gains less spectacular. In place of a desirable natural environment man now has, all too usually, smog, noise, urban sprawls, junk yards, strip mines, and dirty water. Many of these are by-products of our use of energy conversions. If we want to lessen or eliminate these by-products, we must give particular attention to our energy consumption and to the methods we use to obtain power for our technology.

The annual consumption of all forms of energy in the United States has increased nearly twentyfold in the past century. [1, 2, 9, 11, 13, 14] (See Figure 1.) During this period, fuel sources have shifted steadily. Fuel wood was the dominant energy source in 1850. By 1910 coal accounted for about 75 percent of the total energy consumption, and fuel wood had declined to some 10 percent. In the 50 years between 1910 and 1960 coal lost its leading position to natural gas and oil. Today nuclear power is emerging as a national energy source. [15]

Mr. Henderson is a graduate student and Dr. Johnson is chairman of the Chemical Engineering Department at the University of Colorado, Boulder.

THE science of energy is called thermodynamics. Through a study of thermodynamics we learn to calculate quantities of energy. Energy itself appears in many different forms. Water at the top of a waterfall has more energy than it has at the bottom; this is called *potential* energy. When the water flows downhill, the potential energy is converted into energy of flow called *kinetic* energy; this then rotates some type of turbine and eventually creates *electrical* energy, which then can be transmitted along power lines. Energy stored in a fuel may be called *chemical* energy. A substance by its very existence possesses *internal* energy.

There are two ways by which energy is transmitted from one place to another. *Thermal energy* (heat) is energy in motion because of a temperature difference. *Work* is broadly defined as a force moving through a distance and takes on many forms. Thermodynamics allows one to calculate quantities of energy in one form, given some process by which work and heat transfer energy from some other form.

Many books have been written on this subject, yet the basic principles of thermodynamics are summarized in a few very straightforward and deceptively simple rules. One is that energy is conserved in all normal processes. (The loophole "normal" is left because in nuclear processes there is a conversion between matter and energy.) This is the First Law of Thermodynamics. The Second Law of Thermodynamics imposes some limitations on the amount of useful work that can be ob-

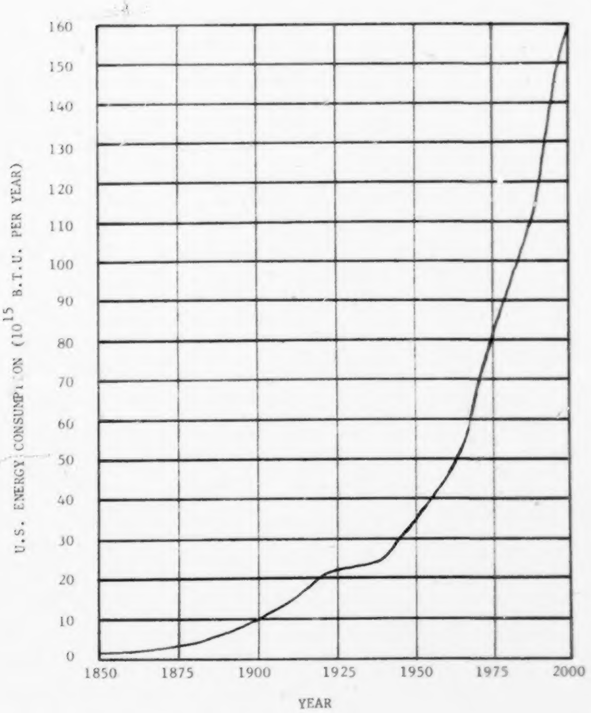

Figure 1. U.S. energy consumption (from U.S. Bureau of Mines).

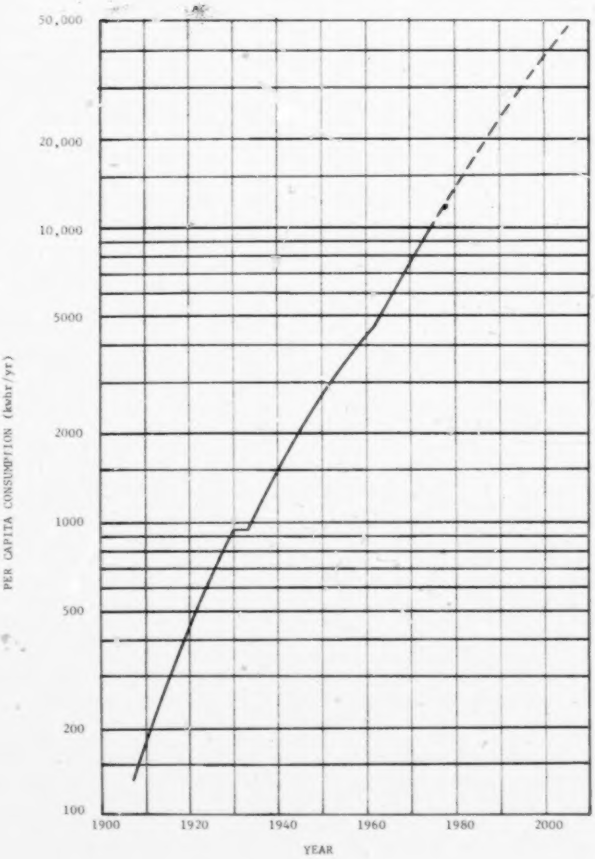

Figure 2. Per capita consumption of electricity in the U.S.

tained when some form of energy, such as chemical, is converted into thermal energy. This latter process occurs in an automobile or power plant. When the fuel is burned, it produces high temperature gases, which are used to move the pistons of an internal combustion engine or to turn the turbine of a power plant. Under these circumstances only a relatively small amount of the energy can be converted to useful work, the remainder is rejected to the surroundings. The Second Law of Thermodynamics allows the calculation of limitations on processes.

Man wants energy for two reasons. One is for heat since he tends to live in climates that are at times harsh. He also needs energy to "do things with," such as propel an automobile or operate electrical equipment. (Man also, of course, expends a considerable amount of biological energy since he still does some things for himself without the aid of electrical gadgets. This paper will not attempt to address any biological problems.)

IN THE conversion of energy from one form to another, two vastly different types of environmental disturbances are created. These are heat and chemical pollution. Some authors define "pollution" as resources out of place or in the wrong place at the wrong time. Certainly the rejection of heat or chemicals to the surroundings does represent a waste of potential, as well as an increase in what we call pollution.

When air pollution is discussed, fingers point at two major culprits. First is the internal combustion engine. Most such engines are installed in automobiles. They form a very difficult type of pollution to combat because these sources are mobile, hard to trace, and each one individually contributes very little pollution. The automobile exhaust may contain unburned hydrocarbons, partially burned hydrocarbons (such as carbon monoxide), nitrogen oxides (which are fixed as a result of the sudden high-temperature combustion followed by a sudden quenching of the gases), and possibly lead compounds, as well as large quantities of carbon dioxide and water. The latter two, of course, fit nicely into the overall biological cycle, and so, unless used or generated in excessive quantities, are little cause for concern. Because there are some 80 million automobiles in this country, auto exhaust adds up to a serious air-pollution problem. There is also some thermal pollution because much of the energy of gasoline is wasted in the form of heat. At present, this heat is rejected to the atmosphere and does not seem to cause any particular problems. However, we can not say that this heat may not become an important problem source in the future.

The other culprit in creating air pollution is the power plant. In this case there may be fewer hydrocarbon emissions, but more fly ash as well as sulfur gases. In regard to some of the newer and larger power plants there is considerable fear that low-grade coals mixed with miscellaneous, and often unidentified, mineral deposits will tend to give fly ash that contains metals such as mercury, molybdenum, and cadmium, the effects of which are really unknown. These effects may be biological if the metals eventually become dissolved in water and affect aquatic life, plants, and man. Large power complexes, such as those located in the Four Corners area (of Colorado, Utah, Arizona, and New Mexico), are obviously causing a distribution of materials over vast land areas; this is obvious from the reduction in visibility in that once attractive part of the country. This reduction of visibility is due rather directly to large quantities of particulate material. It is not known what effect this will have eventually on the biological cycle. It is essential that some rather serious and intensive studies be started as soon as possible.

Power plants also tend to produce large quantities of thermal pollution. This problem is often localized because the heat goes into cooling water which is then put back into the streams. Waste heat creates a serious problem. But there is also a great challenge to improve the handling of this heat so that it may become a useful resource.

This paper will not consider the air pollution caused by chemical, petroleum, paper, metals, cement, and other types of industrial plants, although these are extremely serious and should be a subject for later papers.

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The efficiency with which energy in fuel is converted to useful form varies widely, depending on the method of conversion and the end use desired. When wood or coal is burned in an open fireplace, less than 20 percent of the energy is radiated into the room; the rest escapes in the chimney. A well-designed home furnace, on the other hand, can capture up to 75 percent of the energy and make it available for space heating. The average efficiency of the conversion of fossil fuels for space heating is now probably between 50 and 55 percent, or nearly triple what it was at the turn of the century. In 1900 more than half of all the fuel consumed in the United States was used for space heating; today less than a third is so used.

The most dramatic increase in fuel-conversion efficiency in this century has been achieved by the electric-power industry. [10, 16] In 1900 less than 5 percent of the energy in the fuel was converted to electricity. Today the average efficiency is around 33 percent. The increase has been achieved largely by increasing the temperature of the steam entering the turbines that turn the electric generators and by building larger generating units. In 1910 the typical inlet temperature was 500 degrees Fahrenheit. The latest units take steam superheated to 1,000 degrees.

The maximum theoretical efficiency of a steam turbine or other heat engine is expressed by the fraction $(T_1 - T_2)/T_1$, where T_1 is the *absolute* temperature of the working fluid entering the heat engine and T_2 is the temperature of the fluid leaving the engine. For example, with T_1 of 1,000°F (or 811°K) and T_2 of 100°F (311°K), the equation gives a maximum theoretical efficiency of about 60 percent. However, the heat cannot all be introduced at this constant upper temperature, so the maximum theoretical efficiency is closer to 53 percent. Present-day steam turbines achieve about 90 percent of this, with a resulting overall efficiency of about 48 percent.

These figures deal with the conversion of thermal energy to electrical energy. When the efficiency of the overall plant is calculated, however, the interesting comparison is between the amount of electricity sold to customers and the amount of fuel purchased. Inefficiencies in boilers (about 88 percent) and other power-plant equipment reduce the overall efficiency to about 41 percent.

Present-day nuclear plants must operate at lower temperatures than do fossil-fueled plants, resulting in fuel-to-electricity efficiency of only about 30 percent. Thus, the potential thermal pollution from a nuclear plant is almost 50 percent more than that of a fossil-fueled plant with the same electrical power output.

The challenge is to find something useful to do with large volumes of low-grade energy. Many uses have been proposed, but they seem to run up against economic limitations. The low-pressure steam discharged from a steam turbine has been used for space heating in New York. Chemical plants and refineries also use low-pressure steam from turbines as process steam. This is being done in Midland, Michigan. Heated water released by power plants might be beneficial in speeding the growth of fish and shellfish in certain localities, or for keeping open a pond for waterfowl, as in Boulder, Colorado. Nationwide, however, there seems to be no attractive use for the waste heat; a sad fact when the impending shortages of fossil fuels are considered.

Intimately related to problems of heat discharge from power plants is the problem of weather modification caused by urbanization. [5, 6, 8, 12] Cities are often situated very near the power plants that service them with electrical power. By far the most pronounced and locally far-reaching effects of man's activities on microclimate have been in cities. The change in the heat balance (solar radiation plus man-made production less consumption) is substantial.

When a rural area is changed to an urban one, a spongy surface of low heat conductivity is converted into an impermeable layer with high capacity for absorbing and conducting heat. Also, the albedo or reflective power is usually lowered. These radical changes in surface lead to rapid runoff of precipitation and consequently to a reduction in local evaporation. This is, of course, equivalent to a heat gain—one which is amplified by radiative heat gain resulting from the lowering of the albedo. This heat is effectively stored in the stone, concrete, asphalt, and deeper compacted soil layers of the city. Therefore, structural features alone favor a strongly positive heat balance for the city. To this, local heat production is added. The end result is what has been called the urban heat island, which leads to increased convection over the city and to a city-induced wind field that dominates when weather patterns favor weak general air flow.

An immediate consequence of the heat island of cities is increased convection over cities, especially in the daytime. This has been beautifully demonstrated by the lift given to constant-volume balloons launched across cities. The updraft together with the large amount of water vapor released by combustion processes and steam power lead to increased cloudiness over cities.

IN AN effort to eliminate some of these problems, novel energy conversion systems are now under development. Two devices that have received much notice are the fuel cell and the magnetohydrodynamic (MHD) generator. The fuel cell converts chemical energy directly into electricity; fuel cells have been developed that can "burn" hydrogen, hydrocarbons, or alcohols with an efficiency of 50 to 60 percent. MHD is potentially capable of serving as a high-temperature "topping" device to be operated in series with a steam turbine and generator in producing electricity. Some time ago MHD was being advanced as the energy converter of the future. In such a device the fuel is burned at a high temperature, and the gaseous products of combustion are made electrically conducting by the injection of a "seed" material, such as potassium carbonate. The electrically conducting gas travels at high velocity through a magnetic field, and in the process creates a flow of direct current. If the MHD technology can be developed, it should be possible to design fossil-fuel power plants with an efficiency of 45 to 50 percent. Since MHD requires very high temperatures, it is not suitable for use with nuclear-fuel reactors, which produce a working fluid much cooler than one can obtain from a combustion chamber fired with fossil fuel.

If ever an energy source can be said to have arrived in the nick of time, it is nuclear energy. Twenty-two nuclear power plants are now operating in the United States. Another 55 plants are under construction, and more than 40 are on order. (At the time of writing this paper most construction had been halted because of the failure of the Atomic Energy Commission to file appropriate environmental impact statements.) This year the United States will obtain 1.4 percent of its electrical energy from nuclear fission; it is expected that by 1980 the figure will reach 25 percent and that by 2000 it will be 50 percent.

Other power schemes have been proposed, based on using the wind or solar energy collected at the earth's surface. Their great virtue lies in the fact that they would add no heat load to the earth's biosphere; they can be called *invariant* energy systems. Solar energy collected in orbit would not strictly qualify as an invariant system since much of the radiant energy intercepted at an altitude of 22,300 miles would otherwise miss the earth. Only the fraction collected when the solar panels were in a line between the sun and the earth's disk would not add to the earth's heat load. On the other hand, solar collectors in space would put a much smaller waste-heat load on the environment than do fossil-fuel or nuclear plants. Of the total energy in the microwave beam aimed at the earth all but 20 percent or less would be converted to usable electric power. When the electricity was consumed, of course, it would end up as heat. [See the article by Peter Glaser, p. 120-123.]

To appreciate the long-term importance of developing invariant energy systems one must appreciate what exponential growth of any quantity implies. The doubling process is an awesome phenomenon. (Figure 2) In any one doubling period the growth quantity—be it energy use, population, or the amount of land covered by highways—increases by an amount equal to its growth during its entire past history. For example, during the next doubling period as much fossil fuel will be extracted from the earth as the total amount that has been extracted to date. During the next 10 years the United States will generate as much electricity as it has generated since the beginning of the electric era.

In 1970 the United States consumed 1,550 billion kilowatt hours of electricity. If this were degraded into heat (which it was) and distributed evenly over the total land area of the United States (which it was not), the energy released per square foot would be 0.017 watt. At the present doubling rate, electric power consumption is being multiplied by a factor of 10 every 33 years. Ninety-nine years from now, after only 10 more doubling periods, the rate of heat release will be 17 watts per square foot, or only slightly less than the 18 or 19 watts per square foot that the United States receives from the sun, averaged around the clock. Long before that the present pattern of power consumption must change, or the technology needed for invariant energy systems must be developed.

PERHAPS the most fundamental question of national policy is: How should present resources be allocated for the benefit of future generations? The development of new speculative energy resources is an investment for the future, not a means of remedying the problems of today. It is equally clear that the quality of life of the peoples of the world depends on the availability "now" of large amounts of low-cost energy in useful forms. This being so, orderly development of the resources available with present technology must be emphasized, and these are primarily power plants based on fossil fuels and nuclear fission.

A first step in restraining energy growth would be to give more serious attention to population growth. Population control is also basic to protecting the environment in all its aspects. Pollution is by and large the by-product of an affluent society, not of poverty. This fact is overlooked by people who think of population control as a program necessary only where there is a shortage of food. But population control is only part of the answer, because the major growth in energy demand is due to the continuing increase in the per capita consumption of electricity. [3, 7, 17]

It may be that energy consumption is growing so fast in part because the price does not include the full cost to society of producing and delivering it. Efficient power production is just as important as ever to economic growth, but man deludes himself and perhaps shortchanges future generations when the price of electricity does not include the cost of the damaging impact its production imposes on the air, water, and land. If the total social cost of electricity were included in its price, consumers would be better prepared to consider the effect of their decisions on the environment.

Suggested Student Problems

It is important that man have heat for several purposes in addition to the industrial processing of materials. Primarily, heat is used for comfort and for cooking purposes. Investigate the amount of heat used to warm a home. This can be done by estimating the amount of fuel used and its heating value per unit quantity (British Thermal Units per cubic foot of gas or per pound of coal).

Now assume that the home was heated directly by electricity. How much would this heat cost as opposed to the direct cost of fuel? Taking into account the Second Law of Thermodynamics, how much fuel might have to be burned at the power plant in order to furnish this electricity? (Note that energy such as electrical can always be converted 100 percent into thermal energy.)

In some distant future, fuels may be so expensive that we will no longer be able to afford the luxury of electric stoves and ovens. Because of the same Second Law limitations, the production of heat in a stove by electricity is more costly of fuel when carried out electrically than by gas or other direct method of firing. Make similar calculations to the above showing the amount of fuel that would be wasted if every household in this country had an electric stove as compared to a gas stove.

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If 80 million cars go 10,000 miles each per year and they average 10 miles per gallon of gasoline, estimate the amount of gasoline used. How much heat is released by combustion? How much work is done? Assume the conversion of chemical energy to work in the automobile is 45 percent. Assuming that automobiles were converted to battery power, estimate the amount of power that would have to be generated at power plants in order to charge batteries.

Estimate the amount of air pollutants created by automobiles, given some information on the average exhaust composition. What happens as this work is done? If exhaust pollutants were eliminated by use of battery-powered automobiles, estimate the amount of fly ash and sulfur gases that would be emitted from fossil-fuel power plants to generate the power necessary.

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Examine the electrical gadgetry and other power-conversion equipment (power mower, transistor radio, wristwatches, gasoline-powered saw, etc.) around a moderately affluent home. List those considered essential, desirable and frivolous. Make some estimates of the power savings that might occur if the frivolous gadgets were eliminated.

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Given the equations for heating of water, examine how the quantity of heat energy carried away by a stream, such as one flowing past a power plant, might be determined. Recognizing that the temperature and velocity of the water vary both across and with the depth of the stream, how could the amount of heat actually carried away be estimated? If possible, make measurements above and below a power plant in order to determine thermal energy.

Think about similar types of relationships that might be used to determine chemicals diluted in water and carried away. If possible, make measurements above and below a chemical plant or sewage treatment facility. (Techniques and procedures for field measurements are well described in "Investigating Your Environment." [4])

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Talk to a local utility company and find out its capacity and cooling requirements and whether cooling towers, cooling ponds, once-through cooling, or other system is used. Calculate the efficiency of operation.

What is the flow of various rivers in your area, and what sort of heat load could these accept without damage?

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GEOTHERMAL ENERGY

L. J. P. Muffler and D. E. White

GEOTHERMAL energy, in the broadest sense, is the natural heat of the earth. Temperatures in the earth rise with increasing depth. At the base of the continental crust (25 to 50 km), temperatures range from 200°C to 1,000°C; at the center of the earth (6,371 km), perhaps from 3,500°C to 4,500°C. But most of the earth's heat is far too deeply buried to be tapped by man, even under the most optimistic assumptions of technological development. Although drilling has reached 7½ km and may some day reach 15 to 20 km, the depths from which heat might be extracted economically are unlikely to be greater than 10 km.

White [7] has calculated that the amount of geothermal heat available in this outer 10 km is approximately 3×10^{26} calories, which is more than 2,000 times the heat represented by the total coal resources of the world. [1] But most of this geothermal energy is far too diffuse ever to be recovered economically. The average heat content of each gram of rock in the outer 10 km of the earth is only 0.3 percent of the heat obtainable by combusting one gram of coal and is less than 0.01 percent of the heat equivalent of fissionable uranium and thorium contained in one gram of average granite. Consequently, most of the heat within the earth, even at depths of less than 10 km, cannot be considered a potential energy resource.

Geothermal energy, however, does have potential economic significance where the heat is concentrated into restricted volumes in a manner analogous to the concentration of valuable metals into ore deposits or of oil into commercial petroleum reservoirs. At present, economically significant concentrations of geothermal energy occur where elevated temperatures (40°C to >380°C) are found in permeable rocks at shallow depths (less than 3 km). The thermal energy is stored both in the solid rock and in water and steam filling pores and fractures. This water and steam serve to transfer the heat from the rock to a well and thence to the ground surface. Under present technology, rocks with too few pores, or with pores that are not interconnected, do not comprise an economic geothermal reservoir, however hot the rocks may be.

Water in a geothermal system also serves as the medium by which heat is transferred from a deep igneous source to a geothermal reservoir at depths shallow enough to be tapped by drill holes. Geothermal reservoirs are located in the upflowing parts of major water convection systems. (Figure 1) Cool rainwater percolates underground from areas that may comprise tens to thousands of square kilometers and then circulates downward. At depths of 2 to 6 km, the water is heated by contact with hot rock (in turn probably heated by molten rock). The water expands upon heating and then moves buoyantly upward in a column of relatively restricted cross-sectional area (1 to 50 km²). If the rocks have many interconnected pores or fractures, the heated water rises rapidly to the surface and is dissipated rather than stored. If, however, the upward movement of heated water is impeded by rocks without interconnected pores or fractures, the geothermal energy may be stored in reservoir rocks below the impeding layers. The driving force of this large circulation system is gravity, effective because of the density difference between cold, downward-moving recharge water and hot, upward-moving geothermal water.

Many investigators in the past considered the water in geothermal systems to be derived from molten rock at depth. Modern studies of hydrogen and oxygen isotopes in geothermal waters, however, indicate that at least

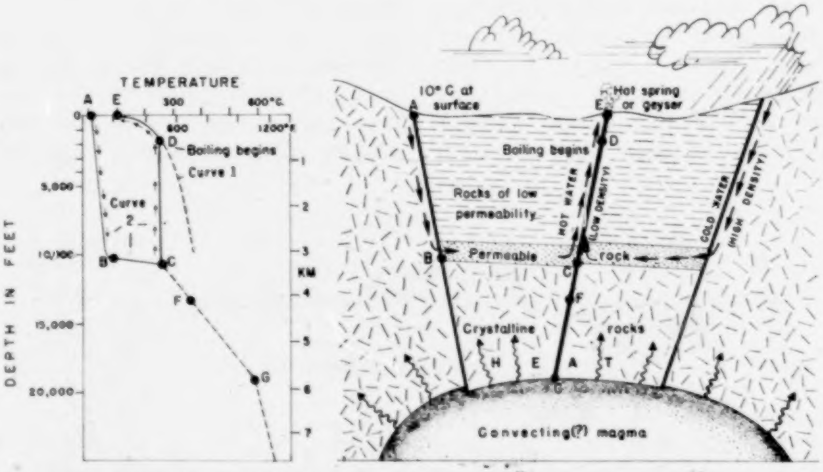

Figure 1. Schematic model of a hot-water geothermal system, modified from White. [8, 9] Curve 1 shows the boiling point of pure water under pressure exerted by a column of liquid water everywhere at boiling, assuming water level at ground surface. Dissolved salts shift the curve to the right; dissolved gases shift the curve to the left. Curve 2 shows the ground temperature profile of a typical hot-water system.

The authors are geologists with the U.S. Geological Survey, Menlo Park, California.

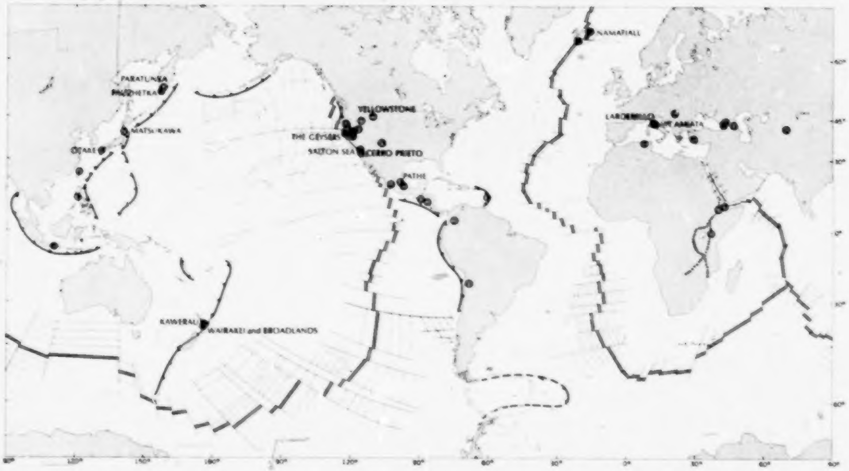

Figure 2. World map showing location of major geothermal fields along plate margins. Heavy double lines represent spreading ridges; heavy lines with barbs represent active subduction zones; heavy dotted lines represent rift valleys. Light lines represent transform faults; dashed light lines represent approximate position of magnetic anomalies. Base map and tectonic features from Coleman. [2, Figure 4]

95 percent of most geothermal fluids must be derived from surface precipitation and that no more than 5 percent is volcanic steam.

Location of Geothermal Systems

Geothermal reservoirs are the "hot spots" of larger regions where the flow of heat from depth in the earth is one and one-half to perhaps five times the worldwide average of 1.5 × 10^{-6} calories per square centimeter per second. Such regions of high heat flow commonly are zones of young volcanism and mountain building and are localized along the margins of major crustal plates. (Figure 2) These margins are zones where either new material from the mantle is being added to the crust (i.e., spreading ridges; see Figure 3) or where crustal material is being dragged downward and "consumed" in the mantle (subduction zones). In both situations, molten rock is generated and then moves buoyantly upward into the crust. These pods of igneous rock provide the heat that is then transferred by conduction to the convecting systems of meteoric water.

Figure 2 shows that the geothermal fields presently being exploited or explored occur in three major geologic environments: (1) along spreading ridges, (2) above subduction zones, and (3) along the belt of mountains extending from Italy through Turkey to the Caucasus. Although this last zone is not a modern subduction zone, it is the zone where the African and European plates are in contact, and it appears to have been a subduction zone in the past. Geothermal fields are absent from the stable, continental shields, which are characterized by lower-than-average heat flow. Although there are no known shallow geothermal reservoirs in the non-volcanic continental areas bordering the shields, hot water has been found at depths of 3 to 6 km in the U.S.S.R., in Hungary, and on the Gulf Coast of the United States. [6]

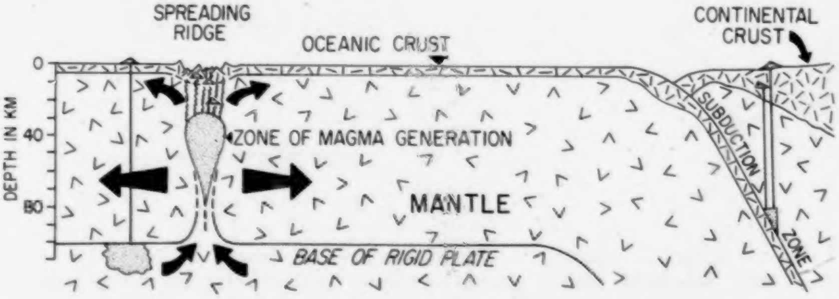

Figure 3. Model of development of oceanic crust at spreading ridges and subduction of oceanic crust at consuming plate margins. [Generalized from Coleman, 2, Figure 6.]

Uses of Geothermal Resources

The primary use of geothermal energy to date is for the generation of electricity. For this purpose, under existing technology, the geothermal reservoir must have a temperature of at least 180°C, and preferably 200°C. Geothermal steam, after separation of any associated water (as much as 90 weight percent of the total effluent), is expanded into a turbine that drives a conventional generator. World electrical capacity from geothermal energy in 1971 was approximately 800 megawatts (Table 1), or about 0.08 percent of the total world electrical capacity from all generating modes. Power from favorable geothermal systems is competitive in cost with either fossil fuel or nuclear power. The production of geothermal power is obviously restricted to areas where geothermal energy is found in sufficient quantity. Unlike coal, oil, gas, or uranium, geothermal steam cannot be transported long distances to a generating plant located near the existing load centers.

Geothermal resources have other uses, but to date they have been minor. Geothermal waters as low as 40°C are used locally for space heating and horticulture. Much of Reykjavik, the capital of Iceland, is heated by geothermal water, as are parts of Rotorua (New Zealand), Boise (Idaho), Klamath Falls (Oregon), and various towns in Hungary and the U.S.S.R. Geothermal steam is also used in paper manufacturing at Kawerau, New Zealand, and has potential use for refrigeration. Some geothermal waters contain potentially valuable by-products such as potassium, lithium, cal-

Table 1. World geothermal power production, 1971.

Country	Field	Electrical Capacity, MW Operating	 Under Construction	
ITALY	Larderello	358.6		
	Mt. Amiata	25.5		
U.S.A.	The Geysers	192	110	
NEW ZEALAND	Wairakei	160		
	Kawerau	10		
JAPAN	Matsukawa	20		
	Otake	13		
MEXICO	Pathé	3.5		
	Cerro Prieto		75	
U.S.S.R.	Pauzhetka	5		
	Paratunka [a]	.7		
ICELAND	Namafjall	2.5		
		790.8	185	$\Sigma = 975.8$

[a] Freon plant.

cium, and other metals. Use of geothermal energy to desalt geothermal water itself has been proposed, and the U.S. Bureau of Reclamation and the Office of Saline Water are presently developing a pilot operation for producing fresh water from the geothermal waters of the Imperial Valley, Southern California.

Types of Geothermal Systems

There are two major types of geothermal systems: hot-water systems and vapor-dominated ("dry-steam") systems. [11] Among geothermal systems discovered to date, hot-water systems are perhaps twenty times as common as vapor-dominated systems. [10]

Hot-water geothermal systems. Hot-water geothermal systems contain water at temperatures that may be far above surface boiling, owing to the effect of pressure on the boiling point of water (curve 1 of Figure 1). A typical hot-water system has temperature-depth relations similar to those of curve 2. Little change in temperature occurs as meteoric water descends from *A* to *B*, heat is absorbed from *B* to *C*, and from *C* to *D* the system contains water at nearly constant temperature (the "base temperature"). From *D* to *E* pressure has decreased enough for water to boil, and steam and water coexist. In major zones of upflow, coexisting steam and water extend to the surface and are expressed as boiling hot springs and locally as geysers. Geothermal wells, however, are usually sited in nearby cool, stable ground where near-surface temperatures are controlled by conduction of heat through solid rocks; the temperature-depth curve is therefore initially to the left of curve 1.

Water in most hot-water geothermal systems is a dilute solution (1,000 to 30,000 milligrams per liter), containing mostly sodium, potassium, lithium, chloride, bicarbonate, sulfate, borate, and silica. The silica content and the ratio of potassium to sodium are dependent on temperature in the geothermal reservoir, thus allowing prediction of subsurface temperature from chemical analysis of hot springs. [3, 4]

In hot-water geothermal systems, only part of the produced fluid is steam and can be used to generate electricity with present technology. For example, water at 250°C will produce only about 20 weight percent of steam when the confining pressure is reduced to 6 kilograms per square centimeter, the approximate well-head pressure commonly used in geothermal installations. The steam and water at this pressure are mechanically separated before the steam is fed to the turbine.

Some attention is currently being directed toward a heat exchange generating system. Heat in the geothermal water is transferred by a heat exchanger to a low–boiling-point fluid, such as freon or isobutane, which is then expanded into a turbine. The geothermal water is not allowed to boil and is reinjected as water into the ground. If this binary fluid generating technology proves economically feasible, it will allow more complete extraction of heat from geothermal fluids and will allow use of hot-water geothermal systems of lower temperature than are presently required for direct geothermal steam generation.

The major known hot-water geothermal fields are Wairakei (160 megawatts) and Broadlands (100 megawatts proposed) in New Zealand, Cerro Prieto (75 megawatts under construction; 200 megawatts proposed) in Mexico, the Salton Sea field in California, and the Yellowstone geyser basins in Wyoming. Although the Yellowstone region is the world's most intensive display of hot-spring and geyser phenomena, the area is permanently withdrawn as a National Park and will never be exploited for power.

Whereas the salinities of most hot-water fields are 0.1 to 3 percent, the Salton Sea geothermal reservoir contains a brine with more than 25 percent by weight of dissolved solids, mainly chloride, sodium, calcium, and potassium. In addition, the brine is rich in a variety of metals. [8] Although temperatures reach 360°C, development of the field has been hindered by problems of corrosion, deposition of silica, and disposal of unwanted effluent. Hot, saline brines also occur in pools along the median trench of the Red Sea where geothermal fluids discharge directly onto the sea floor 2 km below sea level. [8]

Vapor-dominated geothermal systems. Vapor-dominated geothermal systems, in contrast to hot-water systems, produce superheated steam with minor amounts of other gases (CO_2, H_2S), but no water. The total fluid can therefore be piped directly to the turbine. Within the vapor-dominated geothermal reservoir, saturated steam and water coexist, with steam being the phase that controls the pressure. With decrease in pressure upon production, heat contained in the rocks dries the fluids first to saturated and then to supersaturated steam, with as much as 55°C superheat at a well-head pressure range of 5 to 7 kilograms per square centimeter. Owing to the thermodynamic properties and flow dynamics of steam and water in porous media, vapor-dominated reservoirs are unlikely to exist at pressures much greater than about 34 kilograms per square centimeter and temperatures much above 240°C. [5] Hot brine probably exists below the vapor-dominated reservoirs at depth, but drill holes are not yet deep enough to confirm the presence of such a brine.

Drilling has demonstrated the existence of only three commercial vapor-dominated systems: Larderello, Italy; The Geysers, California; and probably Matsukawa, Japan. Two small fields in the Monte Amiata region of Italy are marginally commercial. Larderello was the first geothermal field to be exploited, starting in 1904, and is still the largest producer of geothermal power (350 megawatts). The Geysers at present produces 192 mw, but plants under construction will boost capacity to 302 mw in 1972, and ultimate potential is in excess of 500 mw.

The Geothermal Energy Resource

White [7] estimated that the total stored heat of all geothermal reservoirs to a depth of 10 km was 10^{22} calories. This estimate specifically excluded reservoirs of molten rock, abnormally hot rocks of low permeability, and deep sedimentary basins of near "normal" conductive heat flow, such as the Gulf Coast of the United States or Kazahkstan in the Soviet Union. The geothermal resources in these environments are at least 10 times greater than the resources of the hydrothermal systems, but they are recoverable only at much more than present costs. Should production of these geothermal resources someday become feasible, the potential geothermal resource in all reservoir types would be at least 10^{23} calories, which is approximately equivalent to the heat represented by the world's potential resources of coal.

For a hot-water geothermal system, approximately one percent of the heat stored in the reservoir can be extracted and converted into electricity under present technology. For the far less abundant vapor-dominated geothermal systems, perhaps 2 to 5 percent of the heat in the reservoir can be extracted and converted to electricity. Therefore, if the use of geothermal energy continues to be restricted primarily to electrical generation by proven techniques, then the potential geothermal resource to 10 km is only about 10^{20} calories. To a depth of 3 km (the deepest well drilled to date for geothermal power), the resource for electrical generation by proven techniques is even less, approximately 2×10^{19} calories. [7] Use of geothermal resources for other than electrical generation (e.g., heating, desalination, horticulture, etc.) would greatly increase these geothermal resource estimates, perhaps by 10 times, but all these uses involve special geographic and economic conditions that to date have been implemented only on a local scale.

Production of electricity from geothermal energy is presently attractive environmentally, because no solid atmospheric pollutants are emitted and no radiation hazard is involved. But geothermal generation is not without environmental effects. Effluent from either a hot-water or a vapor-dominated system can pollute streams or ground water. Consequently, federal and state regulations require reinjecting objectionable fluids back into a deep reservoir. Thermal pollution is also a problem, particularly in hot-water systems, but it can be solved in part by reinjection of unwanted water and of residual steam condensate. Noise, objectionable gases, visual impact, and subsidence of the land surface due to fluid withdrawal are other problems that are faced in any geothermal energy development.

Geothermal energy is unlikely to supply more than perhaps 10 percent of domestic or world electrical power demand. But in favorable areas, geothermal power may be of major importance, particularly in underdeveloped countries that have few other energy resources.

Although geothermal power was produced in Italy as early as 1904 and in New Zealand by 1955, extensive interest in geothermal resources of the United States has developed only in the past 10 years. Large areas in the western United States appear to be favorable for geothermal exploration, but knowledge of the nature and extent of our geothermal resources is inadequate. Further investigations are necessary, not only of the distribution and characteristics of geothermal reservoirs but also of the various ways in which geothermal energy can be used in the most beneficial and least wasteful manner. □

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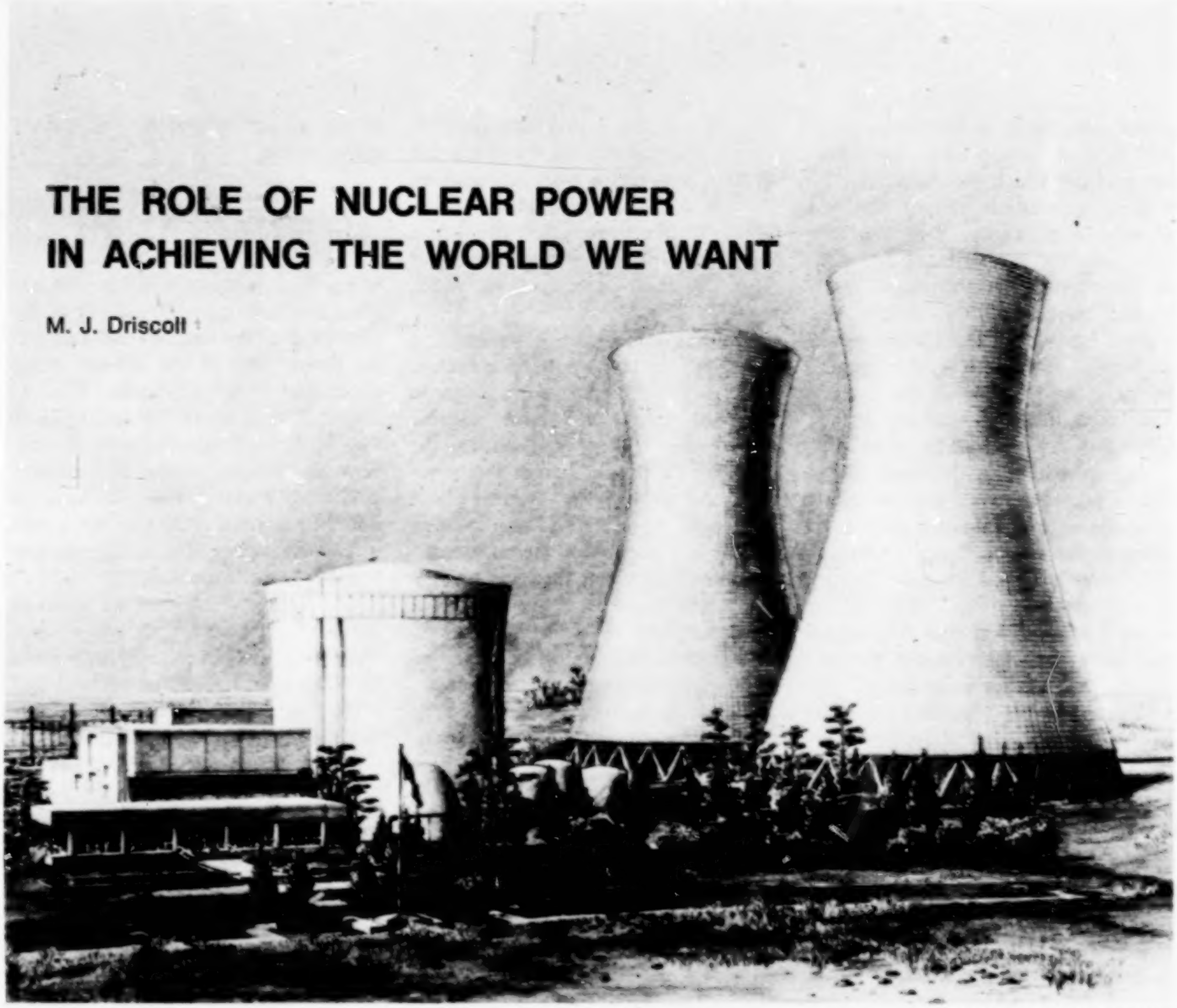
THE ROLE OF NUCLEAR POWER IN ACHIEVING THE WORLD WE WANT

M. J. Driscoll



BABCOCK & WILCOX COMPANY

The huge parabolic water cooling towers will mark the site of the Sacramento Municipal Utility District's Ranch Seco nuclear electricity generating station when the plant—shown in this artist's conception—begins operation in mid-1973. The cooling towers will condense the steam, after it has turned the electricity-producing turbines, for recirculation through the system.

DURING the past year nuclear power has become one of the principal focal points of an often acrimonious debate over the environmental abuses of technology. Two books in particular, *The Careless Atom* by Novick, and *Perils of the Peaceful Atom* by Curtis and Logan,[1] together with a veritable blizzard of magazine and newspaper articles, typify the growing heat, if not light, being brought to bear on this issue.

In their book, Curtis and Logan conclude that we should abandon nuclear power. Many have already criticized their motives, their facts, and their reasoning. Here I will only register the complaint that few of such critics suggest practical alternatives either for meeting the burgeoning demand for electric power or for dampening public enthusiasm for plugging in and turning on at an ever-increasing rate. Their failure to define the problem before suggesting or criticizing solutions prompts me to begin this review with a brief attempt at supplying some compensatory perspective.

NO ONE who has wrestled with one of the bureaucratic service departments of a public utility could be blamed for regarding the entire operation as one of the more staid and static manifestations of American industry. The truth of the matter is that electric power generation is an extremely dynamic field. Electric power usage is currently doubling approximately every 10 years here in the United States. Contrast this with doubling times of 12 years for the U.S. Gross National Product and Research and Development Budget, 15 years for the U.S. supply of scientists, and 37 years for the U.S. population. In other words, the power industry is being forced to forge ahead faster than the supporting bases of capital, manpower, or knowledge available to it. It is also clear that this is one problem which the universal panacea of population control will not alleviate substantially. One can also appreciate the almost inevitable difficulties involved in developing a viable nuclear power industry, which must expand faster than the electric power industry as a whole if it is to capture an increasing fraction of the market. The target doubling time for nuclear plants is a strenuous seven years.

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[1] See entries 1 and 2 under the bibliographic heading "Critical of nuclear power."

Dr. Driscoll is an associate professor of nuclear engineering, Massachusetts Institute of Technology. This paper is based on his NSTA-Sunoco Science Seminar at the 1970 annual meeting of the National Science Teachers Association in Cincinnati, Ohio, in March.

Approximately one hundred central station nuclear power plants are either in operation, under construction, or on order in the United States. Although 1969 sales slumped to only 7 units, projections were that 1970 orders would reach 29 and that this annual rate will be sustained through the next decade. Long-range estimates are that nuclear power will account for roughly half of the total electric generation by the year 2000. Several problems stand in the path to this rosy future: Nuclear installations cost more to build than do fossil-fuel plants and are thus more sensitive to high interest rates; nuclear plant construction has fallen behind schedule as the fledgling industry struggles to tool up to meet its initial large plant orders. Present nuclear plants have a lower thermal efficiency than have coal-fired plants and thus heat up the local environment to a greater extent. If cooling towers are required to avoid overheating the available cooling water, it becomes as much as 50 percent more expensive to so equip the nuclear plant.

In fact, almost every current economic factor would appear to favor the fossil plant except one: The nuclear plant has a lower fuel cost which still enables it to compete on favorable terms in many specific situations. In the near future, as the economic penalties involved in reducing air pollution from coal-fired plants increase, a greater relative savings will accrue to the nuclear plants.

In the slightly more distant future a more serious problem looms: the exhaustion of low-cost uranium reserves. This may well occur over the next 20 to 30 years if the present light-water reactors continue to dominate the U.S. scene. This unhappy prospect has led most of the major nuclear countries (including the United States, Russia, Great Britain, France, Germany, and Japan) to focus upon development of the fast-breeder reactor, about which more will be said later.

While from a purely engineering standpoint the balance between nuclear and coal will be struck on the ledger in terms of dollars and cents, nuclear power must still struggle against the less tangible barrier of public acceptance. Although present nuclear plants have been releasing, on the average, less than 1 percent of their total permissible radionuclide discharge, a running battle has been waged by interveners against nuclear installations. The most serious and most recent attacks have been those made on the allowable limits themselves. To put a complicated subject in somewhat oversimplified terms, these limits have been set, in part, on the general presumption that radiation doses smaller than those to which mankind is exposed by nature (cosmic rays, etc.) are acceptable. The critics have been attempting to marshal evidence that this is not sufficiently conservative. Since the effects in question are so small and so probablistic in nature, conclusive evidence is difficult to develop. At present the viewpoint that present standards are safe until proven otherwise seems to prevail among the vast majority of those most directly concerned with radiation safety.

THERE are so many facets to the present debate over technology versus ecology that I have chosen only two for further discussion here: thermal pollution and some selected aspects of radionuclide discharge to the environment.

One area of considerable ecological concern is that of thermal pollution from power plants, both fossil and nuclear. The science of thermodynamics tells us that to produce useful work, here in the form of electricity, we must discard some of the thermal energy liberated at the generating station. The conversion efficiency, *e*, achieved in modern steam plants is about two-thirds of the maximum possible, or Carnot cycle, value:

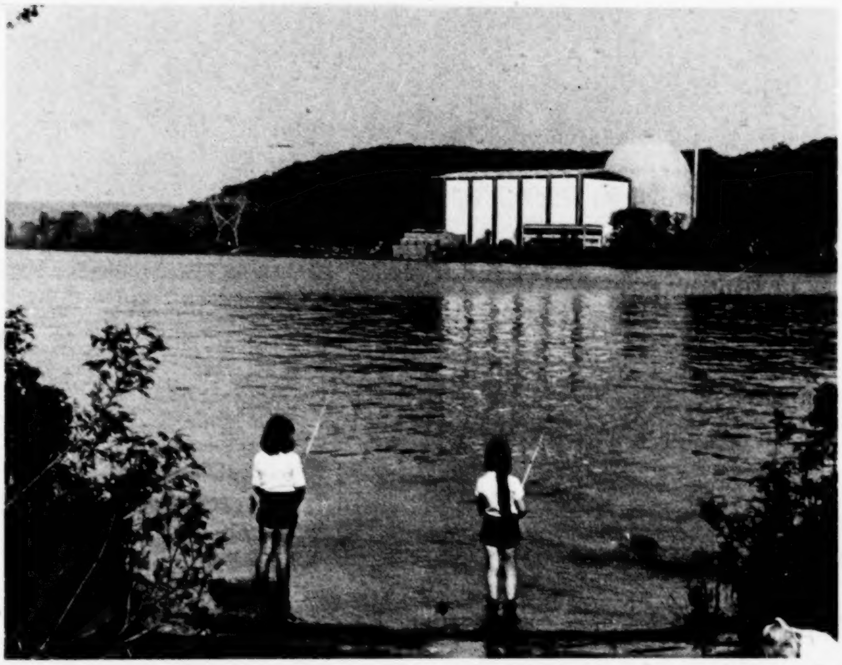
$$e = \frac{\text{USEFUL ENERGY}}{\text{TOTAL THERMAL ENERGY}} \sim \frac{2}{3}\,\frac{T_{\text{HOT}} - T_{\text{COLD}}}{T_{\text{HOT}}}$$

where T_{HOT} is the temperature (in degrees absolute: e.g., °F + 460) of the steam fed to the turbine, and T_{COLD} is the temperature of the exhaust steam discharged to the condenser. For example, if T_{HOT} is 1000°F and T_{COLD} is 100°F, then *e* is approximately 40 percent, an efficiency typical of a modern coal-fired station; while if T_{HOT} is 540°F, *e* is roughly 30 percent, a representative value for a pressurized water-type nuclear plant.

The energy discharged as waste to the local environment per unit of electrical energy produced is proportional to $(1\text{-}e)/e$. Therefore the nuclear plant must dispose of 50 percent more waste heat than must the coal plant.

Since power plants will require a heat sink equal to the entire dry season fresh water runoff in the United States by the year 2000, it is clear that more reliance must be placed on alternate methods in the future. About 20 percent of the nuclear plants now under construction are being equipped with cooling towers, which discharge the waste heat to the atmosphere instead of to local water supplies. Another 5 percent are to use specially constructed cooling ponds. These alternate solutions increase the production cost of electricity about 5 percent: say from 6.0 to 6.3 mills per kilowatt hour for a new plant. Since the average residential customer in the Northeast pays some 42 mills per kilowatt hour for the delivered product, the extra cost of using these alternate heat sinks does not appear prohibitive. Other solutions, such as increased use of oceanside or even offshore siting, are also possible.

While nuclear plants are less efficient than fossil plants at the moment, one should maintain some historical perspective in this regard. In 1920, for example, average coal plant efficiencies were only about 9 percent; in 1950 only 24 percent—a far cry from the present 40 percent. In the future, moreover, the advanced nuclear plants, such



CONNECTICUT YANKEE ATOMIC POWER COMPANY

The Connecticut Yankee Atomic Power Plant at Haddam Neck, Connecticut, is the largest operating commercial nuclear power plant in the United States. The 575,000 electrical kilowatt power facility was started up commercially in 1968.

as the liquid metal cooled fast-breeder reactor discussed later in this review, are projected to match the thermal efficiency of fossil stations.

UNLIKE thermal pollution, which can even be used to advantage in specific situations (fish-farming for example), power plants exact some completely negative tolls on the environment. Sulfur dioxide emission from coal-fired stations and low-level radionuclide release from nuclear stations are a case in point. Although much of the earlier controversy over nuclear power has focused on hypothetical acute accidents which may never occur in fact, recent interest has shifted to the question of chronic exposure to the normal day-to-day releases. This subject is worth some discussion here because debate over this area is bound to demand a greater share of our attention in the future.

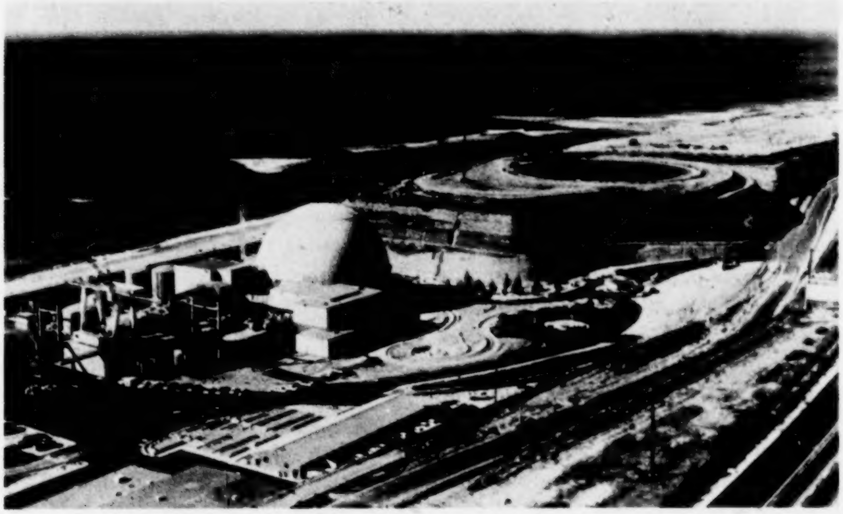
Two radionuclides, tritium and krypton-85, are involved. These two nuclei are produced in approximately 1 and 30 of every 10,000 fissions, and they decay with half-lives of 12.4 and 10.4 years, respectively. At steady state there will be about 85 curies of tritium and 2,500 curies of Kr-85 produced for every megawatt of nuclear power (1 curie corresponds to a quantity of material which contains nuclei decaying at a rate of 3.7×10^{10} disintegrations per second). Once produced, these nuclides must decay somewhere, preferably in a confined area such as the fuel element in which they were produced. Once the fuel element is sent to a chemical reprocessing plant, however, these nuclides can escape to the environment. Tritium will generally escape in the chemical form of water in which one of the ordinary hydrogen atoms is replaced by a tritium atom. Krypton, which is a noble gas, can escape to the air. Although large amounts of radioactivity are demonstrably involved, two factors mitigate the potential problem. One is the enormous reservoir of water and air available to dilute the releases to far beneath permissible concentrations. The second is the fact that the same chemical properties which make it so difficult to prevent release of these nuclides also reduce their potential hazard to biological systems, which find it equally difficult to accumulate large concentrations of these materials.

Although krypton is produced in the largest amounts and would, therefore, be the bigger problem if unrestricted release were allowed, research on cryogenic absorption of krypton is in progress, with some prospects for success. Thus, allowable tritium release may well be the more important long-term question. In fact, if fission reactors are eventually supplanted by fusion reactors, far greater amounts of tritium will have to be handled in the associated chemical processing: The tritium production rate in the fusion reactor is over 100,000 times greater than in the fission reactor!

The total cumulative tritium *production* (but not necessarily release) by

The San Onofre Nuclear Generating Station in southern California will provide 450,000 kilowatts of electricity, enough to supply a city of well over a half-million. Nuclear components are housed in the steel containment sphere near the center of the photo.

SOUTHERN CALIFORNIA EDISON COMPANY



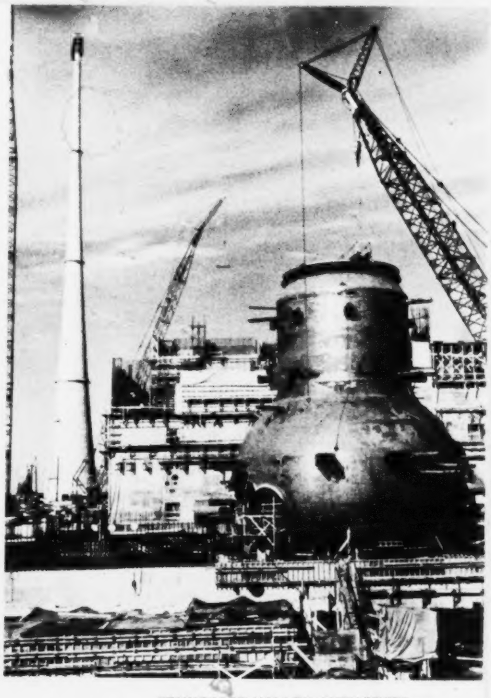
nuclear power plants will equal the natural inventory produced by cosmic rays of approximately 100 million curies somewhere around the year 1995, by which time the 1700 million curies added by weapons testing will have decayed away (barring further tests). Since natural tritium contributes only about one-thousandth of 1 percent of the natural dose due to all sources, this prospect is certainly no cause for panic. Rational evaluation of the facts of this situation by the general public is a necessity, however.

ONE of the most interesting applications of nuclear power, which may become important in the future, involves exploitation of one of its strong points: great flexibility in plant location because of low fuel transportation costs. This has engendered the concept of treating energy as a ubiquitous raw material for use in chemical processing plants. Depending on how inexpensively electric power can be generated, there are numerous valuable chemical products which can be produced using it. Production of acetylene, electric steel, magnesium, aluminum, caustic, chlorine (hence polyvinylchloride plastic), phosphorus, and ammonia are well known to be practical products at present. If power becomes very cheap, then both gas and gasoline could be synthesized from coal. This latter development would obviously be of immense value in assuring a continuing supply of two of our most important but dwindling natural resources. Present estimates are that this type of application will not prove economic until the very distant future. We need not look far, however, to see presently attractive potentialities.

The concept of large nuclear energy centers is frequently combined with the use of dual-purpose power plants which not only produce electricity, but also use turbine exhaust steam to evaporate saline or brackish water to produce fresh water for agricultural use. The electricity can in turn be used to produce phosphorus and ammonia, two important fertilizers. This synergistic system, dubbed the Agro-Industrial Complex, can serve as the nucleus of a high-intensity agricultural effort. While this raises Sunday supplement visions of "making the deserts bloom," particularly in the developing countries, it is a sobering fact that highly sophisticated technology is involved. This requires engineers, technicians, and, most of all, highly skilled farmers, which a developing country may have difficulty in providing. Centers of this agro-industrial type, which vary in the balance among the agricultural, desalting, and industrial functions of the complex, have been studied for construction in Puerto Rico, India, and the Middle East. Those involved are now debating whether the huge capital investment required to build such a plant is the best way to spend the limited resources available for satisfying all of their future needs.

THE OTHER major application of nuclear energy being groomed for the future involves the peaceful use of nuclear explosives. Some of the more spectacular applications, such as digging a new Panama Canal and creation of a deep-water harbor in northern Australia have received most of the publicity, but the more fruitful uses may well be the use of underground explosives to extend the economically recoverable reserves of various natural resources. The Atomic Energy Commission has already conducted tests involving natural gas production. Shale oil recovery is another immensely important area under study.

The use of nuclear electricity to synthesize new supplies of raw materials and nuclear explosives to free-up already existing reserves provides us with a substantial insurance policy against future deprivation. Precisely when these applications will come into more widespread use depends primarily upon economic factors. If the relative cost of electricity continues to decrease and the value of natural resources continues to increase, a crossover point will ultimately result and these alternate schemes will be adopted. In my own opinion, there is considerable incentive for accelerating work on these approaches on national security grounds. For one thing it might substantially decrease the likelihood of the developed countries becoming involved in World War III over allocation of resources such as Middle East oil.



TENNESSEE VALLEY AUTHORITY

TVA's Browns Ferry Nuclear Power Plant under construction at a site on Wheeler Lake, 10 miles southwest of Athens, Alabama. Shown is the containment shell for one of three reactor units. The plant will be the world's largest nuclear power facility, with a total generating capacity of nearly 3½ million kilowatts for the plant's three reactor units. The first unit is scheduled for operation in the fall of 1971, with the other two starting in the spring and fall of 1972.

THE NUCLEAR power plant of the future promises to be of a type substantially different from those now in widespread use. The future plant will probably be the fast-breeder reactor, which has the capability of extending nuclear energy reserves by at least a factor of ten.

Natural uranium in the as-mined condition consists of only 0.71 percent of the readily fissile isotope U-235—the remainder is U-238. Today's light-water-moderated reactors require fuel having about 3 percent U-235, and thus require enrichment of the natural uranium in a diffusion plant. About four-fifths of all of the U-238 ends up discharged as waste from the diffusion plant. This U-238 would be almost worthless except for the fact that after capturing a neutron (and undergoing two successive spontaneous beta decays) it transmutes into the plutonium isotope Pu-239, which is comparable to, and even slightly better than, U-235 as a fissile material. Thus, one can use some of the neutrons produced in a nuclear reactor to convert worthless U-238 into valuable Pu-239. Light-water reactors do this very inefficiently, but sodium-cooled fast reactors are very good for this purpose because they have a greater surplus of leftover neutrons available from the chain reaction cycle. In fact the fast reactor fueled with a mixture of Pu-239 and U-238 can actually breed more Pu-239 from U-238 than is consumed in the energy-producing fission process. In this manner almost all of the vast U-238 reserves can be converted into Pu-239 and used to generate power; the even larger thorium reserves can be converted into fissile U-233 and consumed through a similar breeding process.

Not only does the used fuel from a breeder reactor contain more plutonium than does new fuel, but it should also be possible to create this extra plutonium with a doubling time of 10 years, or exactly in pace with the demand for new electric power. Moreover, this can all be done in a system having a higher thermal efficiency than most other nuclear reactors—an efficiency comparable to that of fossil-fired plants—which will remove the blemish of added thermal pollution. It is interesting to note that unlike the case with thermal neutron reactors, where a wide variety of types have been developed and where national differences are quite pronounced (e.g., light water moderated in the United States, heavy water moderated in Canada, graphite moderated in Great Britain), all national programs reflect exactly the same conclusion on the type of breeder of greatest promise; namely, the sodium-cooled fast breeder.

This remarkable machine will not fulfill these intriguing expectations without considerable engineering development, however. Sodium burns in air and explodes in water. Taming it to the point where a plant can be constructed having the exceptional reliability demanded of an electric power station will require 15 to 30 more years of hard work. Since small-scale pilot plants have already been constructed and have convincingly demonstrated that the basic principles involved are sound, the program is proceeding with confidence in inevitable success.

IT IS difficult to draw definite conclusions on the role of nuclear power in achieving the world we want, because this future role may well be determined on other than the strictly technical and economic questions which have been operative in present and past decision making. For example, the free market for electric power may someday be curtailed. Some have already concluded that this is a necessity; as typified by J. K. Galbraith's statement in a recent article that "For . . . electric power . . . , we are reaching the socially tolerable limits of consumption." Conclusions of this sort are undoubtedly prompted by considerations such as the fact that roughly half of the SO_2 and a quarter each of the particulate matter and oxides of nitrogen in the air come from fossil-fueled power stations. Accelerated adoption of nuclear power would enable us to eliminate this problem or, more correctly, to trade it in for other problems which appear to be less environmentally detrimental and more readily controllable. It is clear that, in order to arrive at a public consensus on some of these rather sophisticated trade-off decisions, science teachers must equip all of our high school students with sufficient breadth and depth of knowledge to properly balance these disparate factors. In the long run it is (or should be) the citizen and voter who sets objectives for the specialist to achieve. At present the United States is producing about 3 million new citizens each year as compared to only 30,000 new engineers and scientists at the BS level. There is every reason to believe that the latter will be even more successful than their predecessors in achieving mastery over nature; thus, it is imperative to ensure that the former are also better equipped to assess and define material needs and objectives compatible with the needs of human nature. ☐

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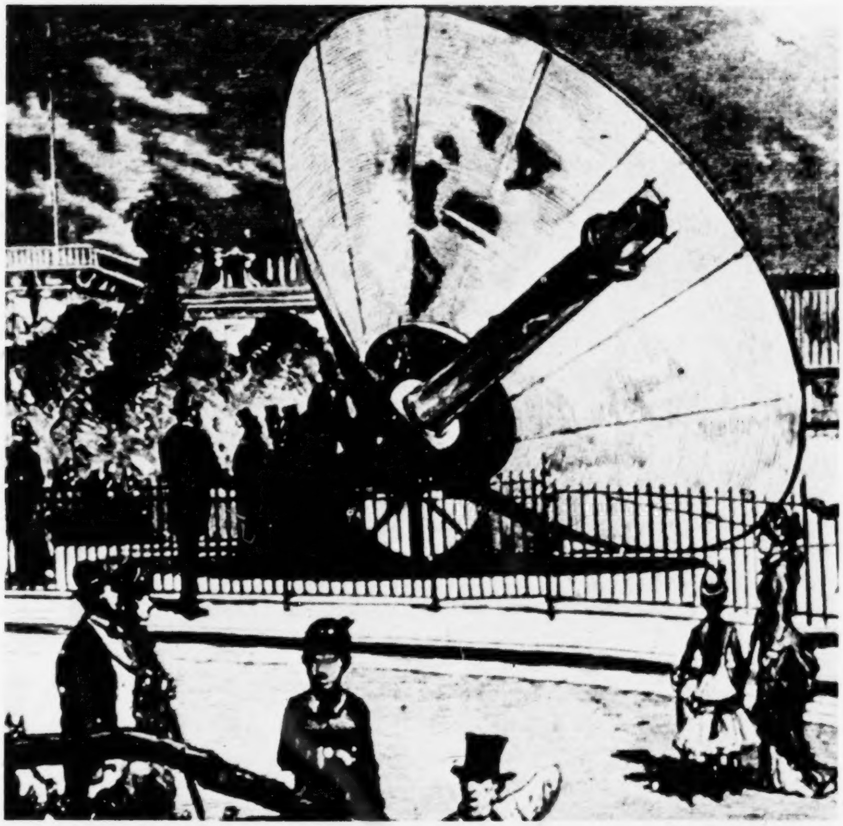


The solar-powered steam engine at the Paris Exhibition of 1878.

SOLAR ENERGY—PROSPECTS FOR ITS LARGE-SCALE USE

Peter E. Glaser

OUR PRESENT efforts to meet the burgeoning demand for energy are proceeding along three paths: increasing the efficiency of fuel plants, developing advanced nuclear power plants, and attempting to control the nuclear fusion reaction. Each line of investigation is both encouraged and constrained by the need to reduce environmental degradation. So are other less advanced efforts, such as the use of geothermal energy or solar energy.

The two desired qualities, abundant energy and minimal side effects, indicate that we cannot ignore our primary energy source—the sun, which has sustained life and led to the complex interrelationships of the earth's ecology. We have always depended on this most abundant energy source, but only for its natural function of providing the earth with a hospitable biosphere through the processes of atmospheric, hydrologic, and oceanic circulation and through photosynthesis.

The sun's energy is low in density (we receive about one kilowatt per square meter at the earth's surface), and it is subject to diurnal, weather, and geographical availability. Nevertheless, the sun provides 178 trillion kilowatts to the earth—about one-half million times greater than the present U.S. electrical power generating capacity, 5,000 times greater than the world's geothermal capacity, and 60,000 times greater than the total tidal energy. We have not tapped more than a minute fraction of this colossal reservoir of energy, even though solar energy is available everywhere, is free of pollution, and costs nothing to supply or distribute.

Solar energy devices if deployed on earth would occupy large areas, which might be a significant diversion of land from alternative uses. The area required depends upon the efficiency of conversion and the quantity of solar energy available in a specific location. If a device with a conversion efficiency of 10 percent were available, one acre of a typical site could produce one million kilowatt hours per year, enough power to supply 200 typical American households. If the 3.2 million acres of land disrupted by strip mining were covered with similarly efficient solar-energy conversion devices, about one million megawatts could be produced when the sun is shining. Thus, the disadvantage of diverting land to solar energy collection would have to be

Dr. Glaser is head of the Engineering Sciences Section at Arthur D. Little, Inc., Cambridge, Massachusetts.

weighed against the benefits to be gained by drawing on this source of energy.

Even if the world's population were 18 billion (a pessimistic projection for the year 2030) and per capita energy consumption were equal to that presently experienced in the United States, the consumption of solar energy would still be very small, only about 0.2 percent of the total solar energy available. The diversion of this small percentage of solar energy to meet human needs would appear to represent little environmental risk. The heat loads imposed on the earth do not increase through the use of solar energy. The concentration of energy consumption, and consequent heat production in large urban centers with high consumption per unit area, may have deleterious local effects, but this problem exists no matter what energy source is employed.

The factors that adversely affect the practicality and cost of the use of solar energy are its high variability because of regular hourly, daily, and seasonal changes and irregular cloud-cover variations. Although these problems can be surmounted through the use of standby power, energy storage schemes, and the like, the task will be difficult. The challenge is to find the means to utilize solar energy on a large scale so that a significant portion of energy demands can be met. This can be accomplished either by constructing large solar power stations with a very high electrical power output or by deploying a large number of individual units to significantly decrease our dependence on other energy sources.

SINCE ancient times, man has tried to take advantage of the sun's energy. More recently he has tried to convert solar energy directly to useful power, one example being the photovoltaic cell. He has also tried the indirect approach—using the sun's heat to dry foods and chemicals and to heat houses and water. He has always been fascinated with concentrating the sun's rays by lenses or mirrors to achieve high temperatures for use in the laboratory or to generate steam to drive engines.

By and large, however, solar energy has been dismissed as being a less feasible means of generating power than other methods. This judgment was understandable in light of the technology available a decade or so ago, but circumstances now dictate that we reappraise this view.

The sun's radiation is readily convertible to heat; one need only provide a surface on which the solar energy can be absorbed. If a fluid such as air or water is then brought in contact with the heated surface, the energy can be transferred into the fluid and subsequently utilized for practical purposes.

This principle is successfully applied in several million domestic hot-water heaters in use in a dozen countries, including Australia, Israel, and Japan. A solar hot-water heater usually consists of a blackened sheet of metal or plastic in a shallow glass or plastic-covered box occupying 10 to 50 square feet of roof area. Water circulates through tubing attached to the surface of the blackened sheet and picks up the heat. The warmed water is then stored in an insulated tank. The tank can be supplied, if desired, with auxiliary heat from an electric heating element or other heat source.

The principle employed in the solar hot-water heaters can be applied to heating homes—all that is required are more or larger solar-heating panels. Enough heat can be absorbed in the circulating water to provide most of the heating requirements of houses in reasonably sunny climates. Of course, the storage tank must be large enough to provide carry-over capacity during short periods of cloudy weather. Conventional energy sources can be used to supplement the solar heater. Instead of water, air can be used as the heat-transfer medium; it is delivered by an air distribution system either directly throughout the house or to a heat storage tank where the heat from the air is transferred to the water or to stones. Reversal of the air flow during cloudy weather allows heat to be taken from this heat reservoir.

In the past 25 years a number of houses and laboratory buildings in the United States, Australia, and Japan have been heated at least partially with solar energy. Most of these installations have been technically successful, and extensive performance data have been obtained on various modifications of air- or water-heating systems.

In most U.S. locations residential heating with solar energy would be somewhat more costly than present conventional means because of the relatively high cost of equipment still under development. If produced on a large scale, however, solar house-heating systems could be competitive with fossil fuel systems, particularly when all of the hidden environmental costs are accounted for. An economic study of residential solar house-heating indicates that, in a least-cost system, about one-half of the total heat supply should be provided by solar energy.

Energy savings achieved through heating homes with solar energy can have a significant impact on our energy consumption, because the energy requirements of the residential housing are nearly 30 percent of total energy consumption. If the solar heating system were designed to supply a larger percentage of the total heat requirement, average costs would be quite high because the cost of solar heating is almost all in fixed capital investment. Because 100 percent of solar heating is not a rational objective, a combination of solar and conventional heat has to be employed. The optimum combination of solar and electric heat, for example, will be that which is equivalent in cost to the cost of electrical power over a 20-year period.

The least-cost, house-heating system will be applicable to the Southwest and Far West. Higher cost systems will be useful at more northerly latitudes (e.g., New York) and in more humid climates. The Southeast (e.g., Florida) is a poor site for solar house heating because the heating requirements are too low to justify such equipment.

Residential cooling systems that rely on absorption-refrigeration cycles will require more technical development before they can use solar-heated water or air from a roof-mounted collector. However, the solar collector would be the same unit used to heat residences, and the cooling unit would be a somewhat more expensive version of the conventional heat-operated air-conditioner. The inherent advantage of solar cooling is that the maximum requirement coincides roughly with the time when the maximum amount of energy is available to operate the system. In addition, the solar collector, which is the most expensive portion of the system, can be employed nearly year-round if cooling is combined with solar heating.

The development of the devices required to cool and heat houses with solar energy has reached the stage where these devices could be available in less than 10 years if a mass market is realized. In mass use, solar heating and cooling devices could easily reduce consumption of conventionally generated electricity by 10 percent. Such a reduction in electrical usage normally translates into a 30 percent reduction in the energy requirements at a power plant. In the year 2000, such a reduction would mean about 120,000 fewer megawatts that our power plants would have to generate.

THE primary advantage of converting solar energy to power is the inherent absence of virtually all of the undesirable environmental conditions ascribed to present and anticipated means of power generation with fossil or nuclear fuels. The interest in producing power with solar energy goes back at least a century. A solar-powered steam engine was a central attraction at the Paris Exposition of 1878. More recently, several imaginative concepts have been proposed for the large-scale utilization of solar energy on earth. Which of these approaches will be the most feasible alternative to present power-generation methods remains to be established. The important fact is that most of them are based on existing technology and well-known physical principles.

Solar energy conversion to electricity on the surface of the earth is intriguing. For example, a 10 percent solar-energy–conversion efficiency would produce 180,000 kilowatts per square mile while the sun is shining.

One possible approach is based on photovoltaic energy conversion employing solar cells. This method relies on the direct conversion of photon energy to electricity in a semiconductor crystal such as silicon. The state of the art of solar cells, based on single-crystal silicon, is well understood, and conversion efficiencies of about 10 percent are reached routinely. The major drawback is that present solar cells are prohibitively expensive because they have been developed primarily to meet the stringent requirements imposed by their application in various spacecraft missions.

New designs for solar cells include microcrystalline cells based on single-crystal solar cell principles or based on organic compounds which exhibit characteristic semiconductor properties. Such designs will likely be developed for mass production possibilities and the consequent cost savings. Or costs may be reduced by partially concentrating solar radiation by means of mirrors to minimize the number of solar cells.

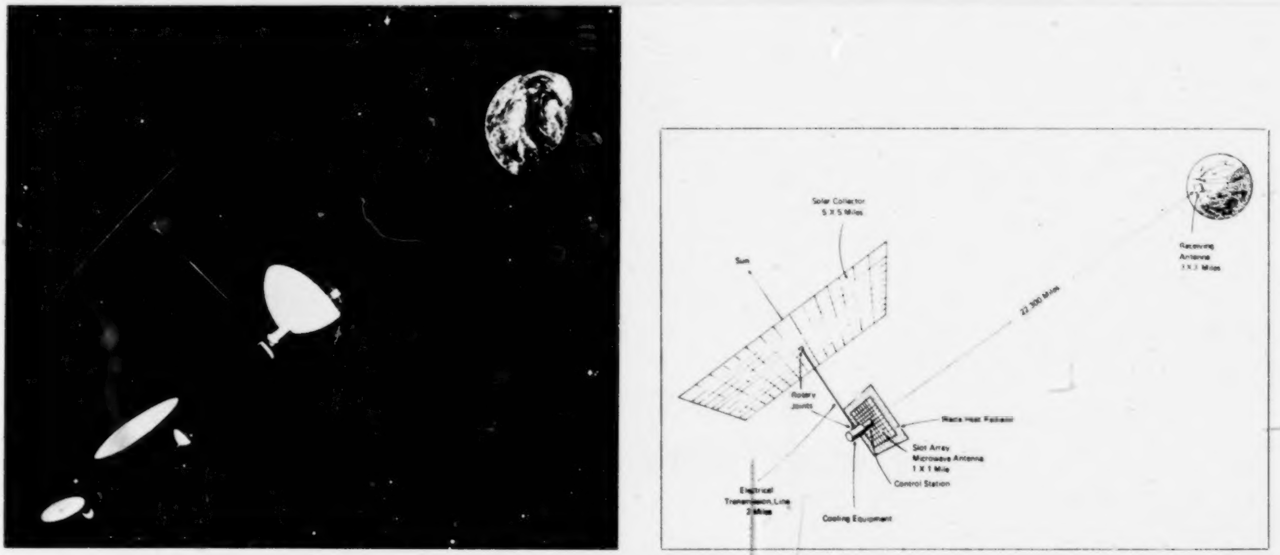
Another approach would make use of the greenhouse effect. This approach involves the use of thin layers of films that selectively absorb radiation. Such films absorb most of the incident solar radiation but emit very little thermal radiation. In principle it should be possible to reach temperatures in excess of 1,000°F if the solar collector is kept under a vacuum.

At present, those thin films that can withstand high temperatures for extended periods have too low an absorptance-to-emittance ratio, less than 20. For efficient conversion the absorptance-to-emittance ratio should be about 40, indicating that an optical concentration of 2 to 4 will be required. A solar power-generating system based on this greenhouse effect has been proposed for the Southwest. For example, a land area of about six square miles covered by such solar collectors would provide the equivalent power output of a conventional 1,000-megawatt station.

> **"We have not tapped more than a minute fraction of this colossal reservoir of energy, even though solar energy is available everywhere, is free of pollution, and costs nothing to supply or distribute."**

The location of a solar power station would be crucial. Even in Arizona, January normally has 9 days in which cloud cover is 0.8 or greater, 7 days in which it is between 0.3 and 0.8, and only 15 days in which it is 0.3 or less. This amount of cloud cover would greatly reduce the solar-energy conversion capability. Thus, energy storage for night periods and overcast days would be required. Whether this would be pumped-water storage, storage in a heat transfer medium or in the form of hydrogen and oxygen produced by electrolysis would have to be carefully evaluated. Land costs, power substations, and transmission lines will substantially affect the economics of operation. An alternative would be a location where solar energy would be available 24 hours a day. This implies that the solar power station should be located in orbit, outside the atmosphere as an earth satellite.

THE successful missions of unmanned spacecraft in earth orbit and to other planets have demonstrated the feasibility of direct conversion of solar energy in space to produce power in the spacecraft and telemeter signals back to earth. On the basis of this experience and the further advances in space technology which can be projected, the concept of a system of satellite solar-power stations has been advanced. Suggestions to use satellite collectors to concentrate solar energy for use on earth



Left, Artist's rendering of a satellite solar-power station. The diagram at right shows a similar station designed to produce 10,000 megawatts of electricity, enough to meet the demands of a city such as New York in the year 2000.

are not new, but the technology now available makes such suggestions practical.

A satellite, when placed in synchronous orbit around the earth's equator, will be exposed to solar energy for 24 hours a day except for short periods near the equinoxes. Lightweight solar cells forming a solar collector of substantial area to produce electricity can be used to power microwave generators. Microwaves in a selected wavelength band can be beamed by an antenna to a receiving station on earth with no significant ionospheric or atmospheric absorption. The receiving station on earth, consisting of a microwave rectifying antenna, converts the microwave to DC electricity which is supplied to the electricity users. A network of such satellite solar-power stations could generate enough power to meet all foreseeable U.S. energy production requirements.

The primary advantage of this approach is that the inefficiencies of the conversion process can be tolerated in outer space because the energy source is inexhaustible. On earth, microwaves could be converted to electrical power with efficiencies of about 90 percent, thereby reducing thermal pollution by a factor of five compared to any other power plants based on any known thermodynamic process.

The power density of the microwave beam would range from one-tenth of the density of solar radiation received on earth at the fringes of the receiving antenna to an amount nearly equal to the solar radiation density in the middle of the array. Beyond the confines of the receiving arrays the beam density would drop to very low values. Since the position of the microwave beam with respect to the receiving array can be carefully controlled, the beam should not represent a health hazard based on presently known biological effects.

A satellite solar-power station of the size envisaged would be capable of producing 10,000 megawatts, enough to meet the demands of a city such as New York in the year 2000. To place such a large satellite in orbit would require an earth-to-orbit transportation system with reusable boosters and space tugs to convey the satellite components to synchronous orbit for assembly.

To develop a system of satellites which could meet future U.S. and eventually world needs will require the application of systems engineering and management techniques which have already been proven in the undertakings associated with the space program. Although the task appears to be immense, so are the opportunities if we can succeed.

WE APPEAR to be at the threshold of a new era of energy production. Before we commit ourselves to pursue any one direction, solar energy, along with its potential large-scale application relative to other technically feasible energy production methods capable of meeting future needs, should be evaluated. This evaluation should involve the definition of standards, criteria, and procedures for analysis on technical, economic, social and political grounds. With such an evaluation, the steps we take over the coming decades can be made consistent with our national goals and broader national purposes.

We can also envisage the possibility of forming a global partnership to develop solar-energy applications to benefit all peoples. Such a partnership might very well mean the realization of the goal so aptly stated by U Thant: "to curb the arms race, to improve the human environment, to defuse the population explosion, and to supply the required momentum to development efforts before the problems facing the world today will have reached such staggering proportions that they will be beyond our capacity to control." [1] ☐

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PROGRESS IN CONTROLLED FUSION RESEARCH

P. L. Auer and R. N. Sudan

POPULAR concern with what many claim is an "energy crisis" in our society has focused attention on several proposed exotic schemes for solving the energy problem. Of these the controlled fusion process is among the more attractive choices. In this article we shall describe briefly the fusion concept, progress in controlled fusion research, and prospects for fusion-produced power.

Both fusion and fission are examples of nuclear reactions which are accompanied by a net release of energy. The resultant heat can be captured, in principle, and converted to electricity or directly to mechanical energy. For many applications it is necessary that the energy release be at a controlled rate. On the other hand, if one is simply interested in an uncontrolled—explosive—release of energy, it is necessary only to initiate the nuclear reactions and confine the reacting mass for very short intervals of time. In practice it turns out to be relatively simpler to make nuclear explosives than it is to develop controlled nuclear reactors. Both fission and fusion processes have been employed successfully in nuclear explosives; to date, however, only the fission process has been tamed successfully in the form of nuclear reactors.

Fission reactions are induced by the collision of a neutron with a target nucleus; if the neutron provides sufficient activation energy, the target nucleus will fragment into two parts of somewhat unequal mass and release additional neutrons plus an excess of energy. In principle, most of the nuclei toward the heavy mass side of the periodic table undergo fission. The nuclei U^{233}, U^{235}, and Pu^{239}, for example, are relatively unstable and can undergo fission upon colliding with low-energy, or thermal, neutrons. The role of the neutron in fission reactions resembles that of a catalyst, particularly when the fissioning nuclei require little or no activation energy, as above.

By contrast, fusion reactions require collisions between two nuclei, which subsequently undergo rearrangement to produce two new nuclei and release an excess of energy. Most of the nuclei on the light mass side of the periodic table undergo fusion, or nuclear rearrangement reactions. Fusion may be viewed as the universal energy source in that it is responsible for the energy produced in stars. In fact, the sun derives its energy from a chain of

The authors are associated with the Laboratory of Plasma Studies at Cornell University, Ithaca, New York. Dr. Auer is director of the laboratory and professor of aerospace engineering, and Dr. Sudan is professor of electrical engineering and applied physics.

fusion reactions by which ordinary hydrogen is converted to helium.

A number of fusion reactions produce neutrons; however, it is important to distinguish that in this case the neutrons do not act as a catalyst but appear simply as a reaction product. More will be said about the role of neutrons in potential fusion reactors later. A source of difficulty in fusion, by comparison with fission, is the requirement that collisions take place between nuclei. All atomic nuclei carry positive electrical charge; therefore, they tend to repel each other. Only relatively energetic nuclei can surmount the coulomb repulsion barrier and collide with each other. Consequently, the specific energy or temperature of the working mixture producing fusion must be hot. In practice, this means that temperatures on the order of 10s or 100s of million degrees Celsius, possibly even greater, are required.

At these extremely high temperatures matter is in the gaseous state, pretty well reduced to its atomic components with the atoms stripped of their more readily removable electrons. That is, the gas is ionized, consisting of positively charged ions and free electrons. This highly ionized state of matter is often referred to as plasma, and the discipline concerned with studying its fundamental properties is called plasma physics.

Fusion Reactions

Of the several fusion reaction possibilities the ones that are of principal interest for controlled fusion application are listed in Table 1. The symbols H, D, T denote, respectively, ordinary *hydrogen* and its isotopes, heavy hydrogen or *deuterium* and super heavy hydrogen or *tritium*; while n denotes the neutron.

The reactions given in Table 1 are listed in order of increasing difficulty except that the second and third, both of which involve deuterium reacting with itself, go with equal probability. Significant differences become evident when we examine these reactions.

Most attention is focused currently on the D-T reaction since it is the easiest on the list. Deuterium is stable and present on earth in approximately one part per 6,500 of ordinary hydrogen. The water on the surface of the earth represents a ready supply of this quantity. However, tritium is slightly radioactive and decays with a half-life of 12.3 years. Because of its relatively rapid decay, it is not available naturally. It can be produced from lithium by neutron bombardment according to the reactions

$$n + Li^6 \rightarrow T + He^4 + 4.8\ MeV$$

$$n + Li^7 \rightarrow T + He^4 - 2.5\ MeV.$$

Thus, a D-T fusion reactor is in fact a "breeder" in which some of the neutrons produced by fusion are used to regenerate tritium in a lithium blanket. Deuterium and lithium, both of which are in abundant supply and relatively cheap, are consumed. The "ash" from the reactor is helium, stable and presumably harmless. One disadvantage of the D-T scheme is the requirement of containing effectively within the reactor large amounts of radioactive tritium.

Conceptually, the D-D fuel cycle represented by the second and third reactions of Table 1 is the most attractive since its fuel is naturally available and essentially inexhaustible. Its "ash" is ordinary hydrogen and helium; the tritium produced is burned up in the reactor and does not accumulate. However, it should be noted that both D-D and the currently favored D-T fuel cycles produce neutrons which in turn induce radioactivity in the reactor structure. The radioactive waste disposal problem which results is practically insignificant when compared with the radioactive waste disposal problems of fission reactors; nevertheless, these fusion reactors will have high levels of radioactivity associated with the structural parts of the reactor which have come under neutron bombardment. An interesting potential side benefit of these neutron-rich fusion reactors is that some of the excess neutrons may be used to "burn up" the radioactive waste accumulated from fission reactors, the long-life fission products.

In both the D-T and D-D fuel cycles the largest fraction of the net energy produced resides in the neutrons and must be recovered in a coolant via a heat cycle. The D-He^3 and H-Li^6 fuel cycles have charged particles only as their reaction products. This opens up the possibility of direct conversion of fusion energy to electricity, avoiding the Rankine cycle and its thermodynamic limitations on conversion efficiency. Unfortunately, the light isotope of helium (He^3) is not naturally available in any significant quantities and must be supplied from the D-D reaction; it is also not possible to suppress completely the D-D reaction in a D-He^3 mixture. Accordingly, the D-He^3 cycle is really a variant of the D-D cycle, adjusted to conditions where the D-He^3 reactions dominate. The production of neutrons is not completely eliminated. The last reaction listed using H-Li^6 has the virtue of completely eliminating neutrons and

Table 1. Fusion reaction possibilities.

FUSION REACTANTS		FUSION PRODUCT	ENERGY RELEASED in MeV
$D + T$	$\longrightarrow$	$He^4 + n$	17.6
$D + D$	$\longrightarrow$	$He^3 + n$	3.25
$D + D$	$\longrightarrow$	$T + H$	4.0
$D + He^3$	$\longrightarrow$	$He^4 + H$	18.3
$H + Li^6$	$\longrightarrow$	$He^3 + He^4$	4.0

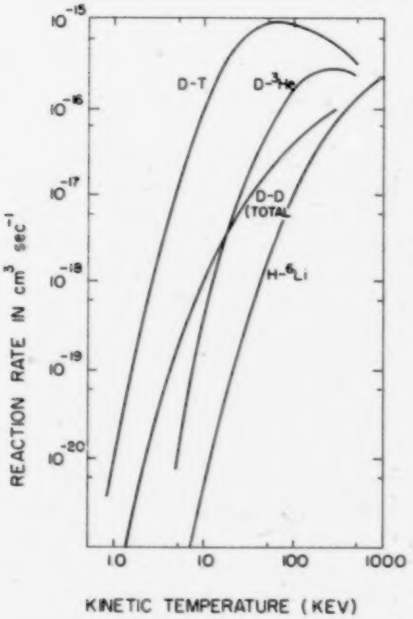


Figure 1. Fusion reaction rate parameter $\langle \sigma v \rangle$ as a function of temperature.

induced radioactivity from the system; it is also the most difficult fuel cycle to contend with, of those listed, in a fusion reactor.

Fusion Feasibility

The high temperatures required in a fusion reactor may be inferred from the behavior of the fusion cross sections as a function of energy. Several illustrative examples are given in Figure 1. Nuclear cross sections are a direct measure of the probability for a given reaction; the rate of a reaction will be proportional to the product of the cross section and the relative velocity of the collision partners multiplied by their concentrations.

All fusion reactors will have to operate above some threshold temperature, usually termed the ignition temperature. This is defined as the temperature where the power produced by fusion reactions just equals the power lost from the reactor by various mechanisms. The most serious loss for a well-behaved reactor comes from radiation. As the temperature increases, the fusion power increases more rapidly than the radiated power (note the rapid initial rise of cross sections with energy in Figure 1; also see Figure 2) and the crossover point defines an ignition temperature. Above this point the fusion process may be considered self-sustaining in the same sense as a flame is, once it has been ignited.

Actually, any practical fusion reactor will be required to operate well above the ignition temperature. If Q represents the energy produced in a single fusion event, then $n^2Q\tau$ is the heat released per unit volume—for example, in a D-D system, where n is the deuterium ion concentration and τ is the duration of time (that is, the confinement time) during which fusion takes place. In addition, the thermal content of the plasma is approximately $\frac{3}{2}\,nkT$, where kT measures the stored thermal energy. If η denotes the frac-

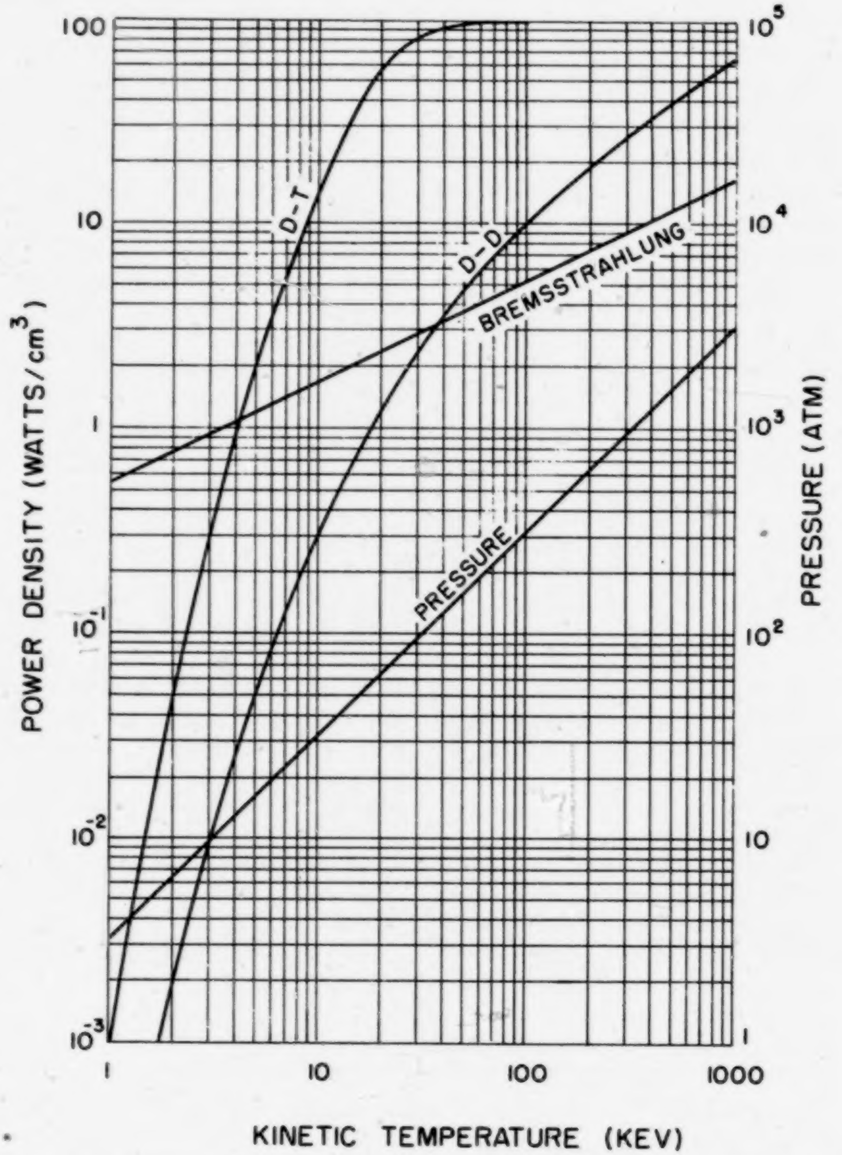


Figure 2. Characteristics of thermonuclear reactions and the ideal ignition temperature at ion density of 10^{15} particles per milliliter.

tion of thermal energy converted to useful work, we have a break-even point when

$$\eta\left[n^2Q\tau + \frac{3}{2}\,nkT\right] = \frac{3}{2}nkT + losses. \qquad (1)$$

The above equation simply states that the useful energy produced by the reactor equals the energy required to reinvest in the reactor. In order to make any excess power, the reactor would have to operate above the break-even point. Achieving the break-even point does, however, constitute a demonstration of feasibility.

At high enough temperatures, we can neglect the losses in equation 1 to get an estimate of feasibility, and we find

$$n\tau = \left(\frac{1-\eta}{\eta}\right)\frac{kT}{Q}\ ; \qquad (2)$$

where we note that for fixed conversion efficiency the right-hand side of equation 2 is simply a function of temperature and the fuel cycle under consideration. For example, assuming a D-D fuel cycle we find equation 2 has a minimum around 200,000,000 degrees Celsius, where we would require

$$n\tau > 10^{14} \qquad (3)$$

providing n is measured in number of particles per milliliters and τ in seconds. This is a statement of the familiar Lawson criterion for feasibility. Under suitable assumptions a variety of similar feasibility criteria can be derived.

From the above it is evident that both temperature and product of plasma density and confinement time are essential for feasibility. In what follows we shall deal with each of these factors in greater detail. The essential point to bear in mind is that the plasma, which constitutes the working fluid of the fusion reactor, must be extremely hot and must be contained within the reactor for sufficiently long times so that the $n\tau$ criterion is more than satisfied.

Plasma Confinement

The requirements set by equation 3 are very stringent. If we choose to operate at a density of 10^{15} particles per milliliter, then we need to confine the plasma for at least a tenth of a second. At thermonuclear temperatures the pressure exerted by this plasma is approximately 30 atmospheres. At higher densities the required confinement time is much shorter, but the plasma pressure is proportionally larger; and, indeed, at very high densities the nuclear reactions would be almost explosive in nature. Although the plasma is at extremely high temperatures, relatively little heat is contained in the working fluid. Were it allowed to come into contact with substantial structural material, the plasma would rapidly cool down rather than vaporize the structure. In order that the plasma not be lost or cooled in the time that it would take a particle to reach the walls, magnetic fields have been proposed to confine it. A magnetic field of strength B exerts a restraining pressure on the plasma of magnitude $B^2/8\pi$, and in actual devices this magnetic pressure must be in considerable excess of the plasma pressure. A useful figure of merit is the quantity β = plasma pressure/magnetic pressure.

The magnetic field squeezes the plasma in the transverse dimensions, but it is still free to stream along the lines of force. In order to confine it in the third direction we have two options. In one scheme the magnetic field strength increases along the lines of force. (Figure 3) Since the plasma behaves like a diamagnetic body, the charged particles are reflected from regions of high field strength, and we have the magnetic mirror confinement concept. This is an example of an open-ended system since the lines of force enter the region filled with plasma and subsequently leave this region. Because the magnetic mirror is never perfect, a leakage of particles always takes place in open-ended systems. In contrast we have "closed" systems in which the lines of force are either closed or they are confined to a finite volume in the topology of a torus. (Figure 4)

Neither the mirror (open) nor toroidal (closed) schemes as described above are adequate for stable plasma confinement, which demands that any displacement about the equilibrium position damp away in the course of time. Plasma stability is insured in a region where the magnitude of the

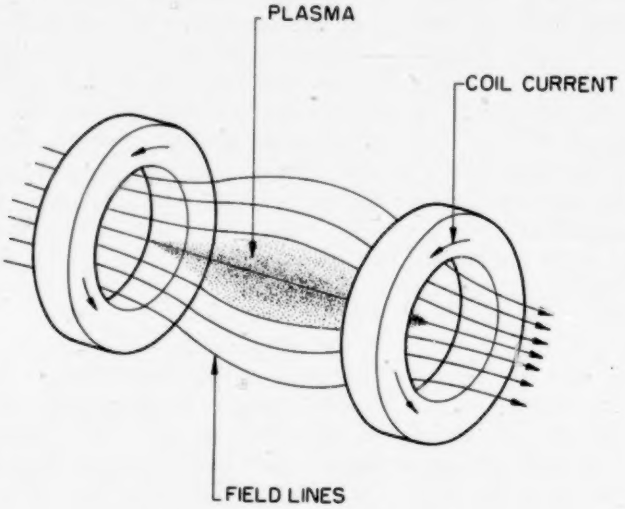
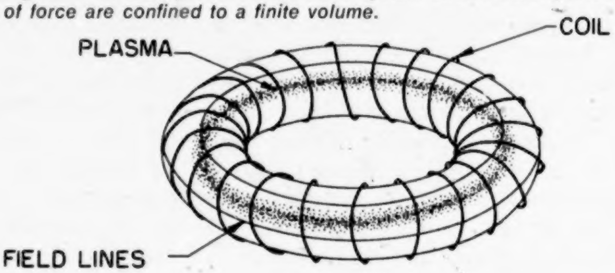


Figure 3. A simple magnetic mirror in which the charged particles are reflected from regions of high field strength. This is an example of an open-ended system.

Figure 4. In a simple torus, a closed system shown below, lines of force are confined to a finite volume.



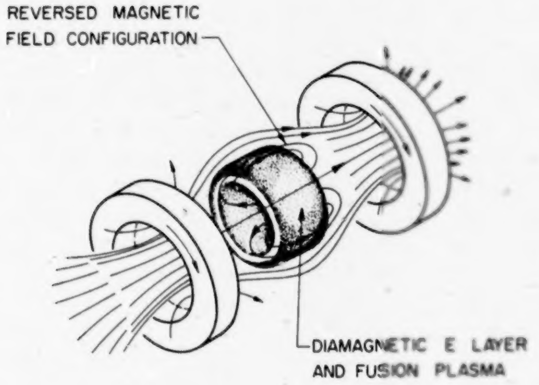

REVERSED MAGNETIC FIELD CONFIGURATION
DIAMAGNETIC E LAYER AND FUSION PLASMA

Figure 5. The Astron configuration for obtaining controlled fusion, which aims to generate a strongly diamagnetic region inside a conventional mirror. It is a kind of hybrid scheme.

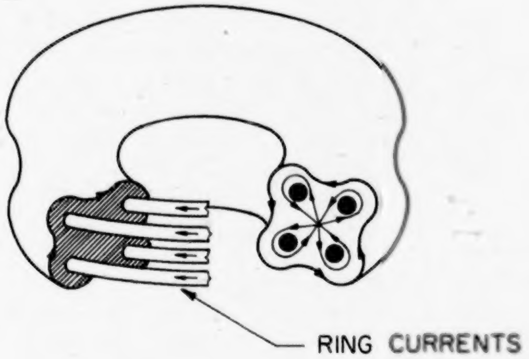


Figure 6. The Octopole is an internal ring device.

magnetic field increases in all directions away from a point of minimum nonzero value. It is relatively easy to achieve a minimum |B| configuration for open-ended systems. On the other hand it is topologically impossible to have such a minimum |B| region in toroidal system unless externally driven currents flow in the plasma. When such a toroidal current is induced by making the plasma the "secondary" of a transformer, we have the Tokamak configuration. (Figure 4) Another variation of this scheme is the Astron (Figure 5) where the internal current is carried by relativistic electrons forming a cylindrical" E-layer," which are in turn confined by a mirror field. This scheme is in some sense a hybrid: The closed lines of force of the magnetic field produced in combination with the "E-layer" encloses the minimum |B| toroidal region while the open lines form a magnetic mirror.

In some experimental devices (Figure 6), currents are induced to flow in levitated conductors embedded in the plasma. The D. C. Octopole at Gulf General Atomic and the Spherator at Princeton University are examples of internal ring machines which have proved very useful for the study of plasma containment but cannot be extrapolated to fusion devices because of particle losses to the floating conductors.

Plasma Diffusion

Even a stably confined plasma suffers from particle losses by diffusion. If the situation were strictly classical, the gyrating particles would at each collision move across the lines of force on the average of a distance equal to their gyro-radius r_i. This leads to a diffusion coefficient $D_c = \nu r_i^2 \propto \nu T/B^2$, where ν is the frequency of collisions of the ions and according to classical theory decreases as $T^{-3/2}$. To confine a cylindrical column of plasma for a time τ given by (3), it must at least have a radius $r_p = \sqrt{D\tau} = r_i \sqrt{\nu\tau} \propto \sqrt{T/B}$; for $n = 10^{15}$, $\tau = 0.1$ sec, $T = 2 \times 10^{8}$°C, and $B = 50$ kg, we obtain $r_p \sim 5$ cm, which is an acceptable figure. However, it is found experimentally that the plasma diffuses very much faster than the classical rate defined by D_c. It is not altogether clear what the exact mechanism for this large diffusion is, and different processes may be operative in different experiments. One explanation of this phenomenon rests on the unusually high level of fluctuations in density and electric field observed to exist in a hot plasma. These large fluctuations result from "micro instabilities," which are present even in a macroscopically stable plasma.

The confined plasma, which is almost never in thermodynamic equilibrium, has a large amount of free energy that is continually released in the form of short-wavelength high-frequency fluctuations. The cross section of particles scattered off these charge fluctuations is large, and this results in large increases in the transport coefficients. In one theory the collision frequency is assumed to be proportional to the gyro-frequency which gives the Bohm diffusion coefficient $D_B \propto T/B$. This scales as B^{-1} as opposed to B^{-2} for the classical situation and appears to increase with temperatures. If Bohm diffusion were to be a universal feature, then the plasma size becomes unreasonably large, and one would have to give up all hopes of successful controlled fusion along the lines under discussion. Fortunately several experiments have shown diffusion much less than the Bohm rate although still in excess of the classical rate. This gives reason to hope that the true coefficient lies somewhere between D_c and D_B. Recent theoretical studies on axi-symmetric systems like the Tokamak and the Astron indicate that the diffusion might be entirely classical except for an enhancement factor $(R/r_p)^{3/2}$, where R is the major radius of the torus, introduced by the curvature of the lines of force which causes the particles to jump distances far larger than the gyro-radius at each collision.

Plasma Heating

Successful heating of the confined plasma to ignition temperatures is the second important problem on the road to controlled fusion. The simplest method is to pass a current through the plasma inductively or otherwise and let it heat by Joule losses. This method becomes less efficient as the plasma gets hotter, because classical plasma resistivity decreases at high temperatures as $T^{3/2}$. On the other hand if a large current is pulsed for a short time, anomalously large resistivities can be achieved, and the transfer of energy to the plasma is improved so that still higher temperatures can be attained. The anomalous resistivity arises because of large fluctuations driven unstable by the current under optimum conditions. This would of course increase particle diffusion as discussed earlier, but the hope is that plasma heats much faster than it diffuses or cools by anomalous conduction losses.

A plasma can also be heated by radio frequency or microwave radiation tuned to any one of its several resonant frequencies. For heating electrons, the frequency generally chosen is the electron cyclotron frequency or its harmonics and similarly for the ions. This method is not very suitable at high densities because of the reduced penetration of the *rf* power into the plasma. At laser frequencies one can afford to have high densities (for a 1 μ wavelength laser, $n \sim 10^{21}$ can be tolerated) and collisional absorption of photon energy can heat the plasma. High-power (10^{13} watts) pulsed lasers have been proposed for heating small pellets of D-T mixture to thermonuclear ignition temperatures, but the low efficiency ($\sim 1\%$) and small pulse energy ($50 \sim 500$ joules) of present-day lasers precludes them from being front runners. There are some indications, however, that a breakthrough in laser application technology could rapidly change the picture.

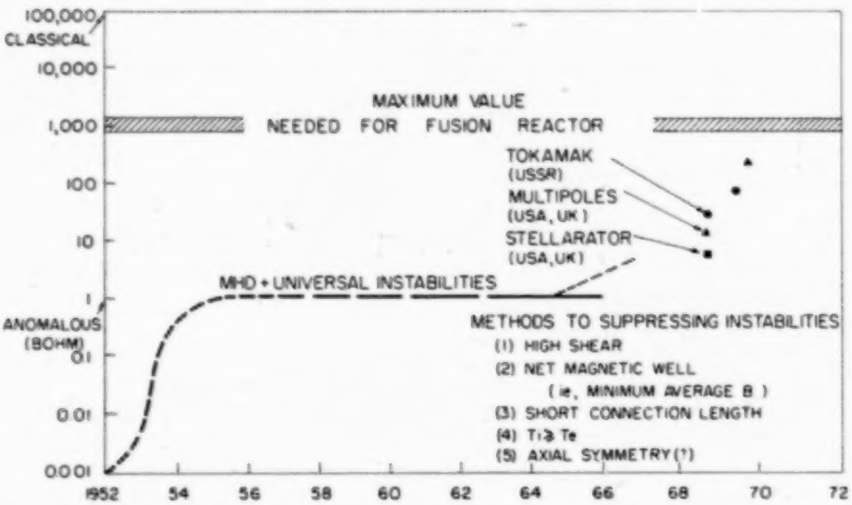


Figure 7. Containment time in toroidal devices (relative scale).

Another useful method is to inject a beam of energetic particles into a magnetic bottle. The subsequent equilibration with the confined plasma results in heating. In one scheme the energetic particles are neutral atoms in excited states. As they enter the magnetic field the Lorentz $V \times B$ force ionizes them, and the resulting electron and ion pair are trapped in the field. The Ormak toroidal device of the Oak Ridge National Laboratory and the Alice mirror machine of the Lawrence Radiation Laboratory rely on this technique. Steady H beams of the order of 2 amps at 30 KeV are currently possible.

Recent developments in technology have led to the generation of electron beams with energies in the range 500 KeV to 10 MeV and currents in the range of 50 KA to 1 MA of pulse durations of the order of 50 nsec. The energy content in these beams is as large as 10^5 J, and the peak power is of order 10^{12} watts. These beams can be used for rapidly heating a plasma to ignition temperatures. Experiments at the Naval Research Laboratory and at Cornell University are presently being set up to investigate the amount of this heating. Injection of these beams into a magnetic mirror readily provides the "minimum $|B|$" geometry required for plasma confinement, as in the Astron. Preliminary experiments at Cornell University show promise in this direction. The idea of creating internal ring machines with relativistic electrons rather than material conductors also seems quite attractive.

Fusion Prospects

Progress in controlled fusion research during the past 10 years has been steady and encouraging. There is a general feeling of optimism within the community concerned with this effort. What is the nature of this optimism?

A kind of progress chart is given by Figure 7. This has to do with the rather notable achievements in confinement times by various experimental approaches. As mentioned previously, progressive improvements have been made in understanding theoretically the origin of various plasma instabilities and learning how to control them experimentally. At this time toroidal confinement in the Tokamak configuration appears to be the most promising. For example, confinement up to 0.01 sec has been achieved with densities of 5×10^{13} at ion temperatures of 5 million degrees Celsius. Scientific feasibility would be achieved with an increased factor of two in density, thirty-five in confinement time, and five in temperature. A modest increase by a factor of two in confinement time beyond this could lead to a practical demonstration reactor, providing an additional increase by a factor of six in density and four in temperature were obtained.

However, it is far too early to decide whether this is the ultimate winner. Certain scaling laws must be tested over a greater range of variation than has been done to date before we can be truly satisfied. In the case of Tokamak this means building experimental machines of one or more generations beyond those already existing or under construction. It takes three to five years to complete such major experiments from the time of concep-

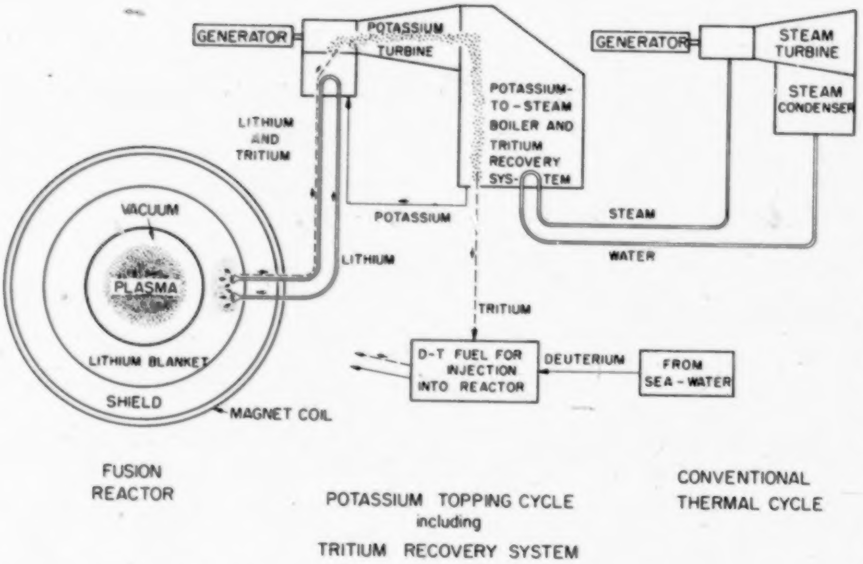


Figure 8. D-T (deuterium-tritium) fusion power plant, a conceptual design.

tion, and that is the time scale on which progress has to be measured.

The end goal of these scientific experiments is to demonstrate feasibility; that is, to meet the break-even point where as much power is produced by fusion as is required to initiate the reactions. From what we know today, it seems that toroidal configurations will have an easier time achieving this than will open-ended ones, simply because the latter tend to be more leaky. However, there are a number of good reasons to continue looking at open-ended approaches. They should be easier to scale to less than giant size (it is conceivable that toroidal reactors will be limited to the 10^{10} watts thermal or even larger unit size), and they are particularly attractive in schemes which directly convert fusion energy to electricity. Finally, no one is prepared to say that there are no more plasma physics surprises in store; thus, it seems only wise to continue research on any of several candidates which look promising.

Many of the experts feel that if the present rate of progress can be maintained, feasibility of controlled fusion will be achieved within this decade, perhaps in as short a time as five to seven years. What then? In Figure 8 we depict very schematically what the first fusion reactor might look like. But, even after feasibility has been demonstrated a lot of hard work will be required before such reactors can be developed. A whole host of technological problems face the prospective reactor developer and these are just now being identified and studied. To mention but a few, there is the problem of finding structural material which can withstand the hostile environment of 14 MeV neutrons (in the case of D-T reactors) plus copious radiation from the hot plasma. Much remains to be done regarding magnetic field generation on the scale required by reactors, although rapid advances in superconductor technology have been of considerable help here. Handling liquid lithium in the presence of strong magnetic fields and injecting fuel into a plasma at 10s of atmospheres of pressure are still further examples of problems to be solved.

Needless to say, the field is still wide open and a number of ingenious approaches, some already in early laboratory stages, may arrive which could abbreviate the development time of practical reactors. An example, the concept of igniting fusion in solid pellets by irradiation with powerful lasers, has caught the imagination of several workers. Even under the most optimistic premises, prior experience with conventional reactors and other advanced technology products leads us to expect that 15 to 20 years will be required to develop commercially acceptable reactors after scientific feasibility is achieved. On this basis, one would predict that fusion reactors will not make a serious impact on the energy supply situation of the world until toward the end of the century. There is a finite possibility that the fusion concept may become practical on an even shorter time scale, in a modified form. Some have speculated that a hybrid fusion-breeder reactor could be developed on a relatively shorter time scale. In this, the copious neutron source of a fusion plasma would replace the core of an orthodox fast fission breeder. Should there be unforeseen difficulties in the fast breeder development program, the fusion breeder hybrid may be worth considering.

The next ten years promise to be a very exciting period for controlled fusion research on both the scientific and engineering fronts. Many concepts still in the laboratory today should be emerging as viable reactor prototypes during this period. As realistic technological problems receive more and more attention, we anticipate that many innovative ideas for solving them will appear. The vision of tapping the limitless energy source of the oceans is spurring on workers in this field. ☐

Further Reading

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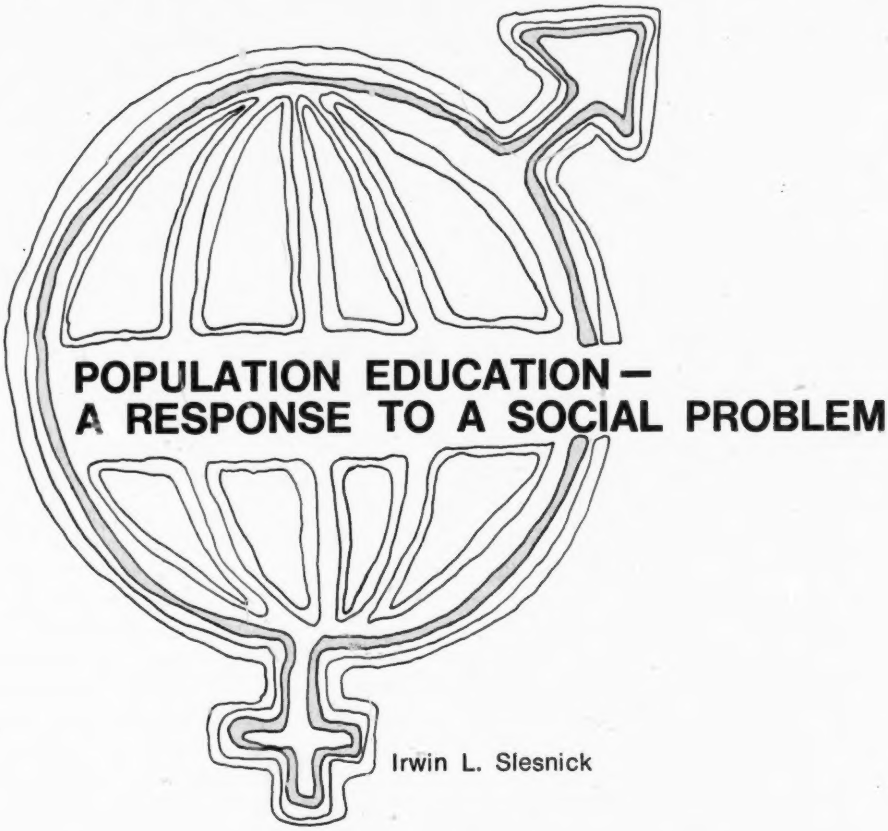
4. *Progress in Controlled Thermonuclear Research.* Division of Research, U.S. Atomic Energy Commission. U.S. Government Printing Office. December 1970.
5. Rose, D. J. "Controlled Nuclear Fusion: Status and Outlook." *Science* 172:797; May 21, 1971.

PART III

ENVIRONMENTAL EDUCATION

Course descriptions and curricula



POPULATION EDUCATION — A RESPONSE TO A SOCIAL PROBLEM

Irwin L. Slesnick

THE phenomenon is excessive human population growth. It originates at the interface of modern technology, traditional culture, and biotic potential. It contributes to war, poverty, hunger, disease, pollution, the erosion of freedom, and the loss of individual identity. The phenomenon is a current social problem, and the action is toward stabilizing world population, with the ultimate aim to achieve and maintain levels of optimum population size.

In recognition of the consequences of overpopulation, each institution of society has begun to move in the direction of population control. Governments are establishing new population policies: liberalizing abortion laws; removing pronatalist tax incentives; funding research in family planning. Similarly, the churches are re-examining their pronatalist policies, and families of two or fewer children are becoming symbols of social responsibility. The school and its external arm, the mass media, have assumed the tasks of disseminating knowledge about the population phenomenon and establishing attitudes that, when translated into behaviors, will prevent the recurrence of population imbalance.

Dr. Slesnick is a professor in the department of biology at Western Washington State College, Bellingham.

Population education, therefore, is one effort to change the reproductive behaviors of modern man through a deliberate program of persuasion. Failure to recognize this as the real goal of population education may lead curriculum pacesetters to statements of vague goals and the staking out of topical territories that only appear to be related to the educational need. A snowfall of instructional materials that results from a perfunctory response to the population problem would do little to support the cause of population control. A random and administratively convenient placement of informational packages about population will not change reproductive behaviors.

The failure of conservation education is a case in point. For the last 50 years or so schoolchildren have been expected to develop wholesome attitudes and acquire knowledge about their physical and biological environments. In classrooms they read and talked about environmental dynamics, saw films and demonstrations, and some even planted trees and lived in the woods. Today the American adult, a product of conservation education, is a world champion polluter. Our environment is being consumed and defouled to such an extent that the citizen must now be controlled by threat of imprisonment and fine, lest he further desecrate his environment. The population education parallel is obvious: Unless individuals learn to control their fertility voluntarily, their reproductivity will be directed by legislated sanctions, not unlike the laws that now attempt to control littering.

Two categories of causes have contributed to the failure of population control efforts thus far. One category is motivation toward family size limitation. Most of the people of the world are driven by a long-established cultural tradition to achieve high fertility. Such forces as religious doctrines, moral codes, public laws, community customs, marriage habits, family organization, and children's literature explicitly and inexplicitly demand high child productivity. Parenthood is fulfillment; and children, especially sons, are wealth, security, and demonstrations of virility. Although motivational problems are more pronounced in developing countries, studies of family size expectations in the United States reveal only slight effects on reducing the present growth rate. The second category is the availability of the means to control conception and birth. No matter how motivated couples may be not to conceive, they must still know how to prevent a conception, where to obtain contraceptives, and how to use them. And all this learning should occur before the first act of sexual intercourse. Population education focuses on the task of motivating individuals to avail themselves of the means to limit their reproduction.

Approximately 50 percent of world population is under the age of 16. It is not realistic to expect to reach these people at the instant of marriage and then change their behavior with information about population and family planning. The mass media messages of the crisis of overpopulation and the benefits of family size limitation occur too late, since the behavior of adults is directed in large measure by the attitudes which develop in childhood. The society that wishes to control the size of its population must influence its youth by creating an awareness of the consequences of overpopulation, the virtues of a small family norm, and an understanding of what they must do individually as adults to achieve the goal of a population of optimum size.

THE FIRST task of curriculum development is to state objectives in ultimate behavioral terms. The primary objective for population education is that each couple voluntarily contracepts, or takes equally effective measures, to limit the size of its family and to space its children. The unfortunate reflex against this objective challenges the propriety of teaching contraception to children, and it becomes necessary to point out that attitudes which produce high fertility behavior are established during childhood in the absence of any instruction of the techniques of producing babies. Societies that are notoriously prudish or Victorian are efficient in perpetuating the attitude that large families have economic and social advantages, and they do this without doing violence to the highly classified information about sexual reproduction. Patterns of adult sexual behavior are established in childhood, and we must realize that any position the school takes within the spectrum of sexual morality has an impact upon ultimate behaviors. Abjection of responsibility is a strong negative position that ensures the persistence of the *status quo*. Even so, there are those who would proceed in the development of a population education while denying or ignoring the ultimate objective. The condition is symptomatic of a kind of cultural schizophrenia, and does not contribute to the development of a curriculum for which the goal is clearly achievable.

Population education, in my view, is distinct from sex education (family life education) and environmental education (conservation education), even though a considerable amount of the content of the programs will overlap. Where population education seeks to change the reproductivity of modern man, sex education seeks to influence the establishment of interpersonal ethics. Where population education seeks to control the number of human consumers of natural resources, environmental education seeks to optimize the relationships between each human and his environment.

A reasonable approach to population education, considering the present subject-centered structure of the educational system, is an infusion of instructional activities appropriately placed in the subject areas of the K-12 span. The alternative is to peg core topics at appropriate grade levels in schools where curriculum is organized to enable an interdisciplinary problems approach to learning. In either case the thrust of population education will occur in areas of the social studies and science. But since the consequences of abnormal population growth permeate all aspects of life, it is logical to expect that every school subject area involve itself in the population curriculum, whether the curriculum is an integrated core or traditionally subject centered.

The resources on population as they relate to the objectives of population education are widely scattered. In the

Major Organizations and Their Involvement in Population Education

1. The University of Delaware, School of Education, Newark, Delaware 19711.
The Population Curriculum Study under the direction of Robert W. Stegner (science) and Val E. Arnsdorf (social studies) will develop K-12 instructional materials for teachers, a strategy for the integration of content in the traditional school curriculum, and a program of preservice and inservice teacher education.
2. Planned Parenthood World Population, 515 Madison Avenue, New York 10022. (Dorothy L. Millstone)
The national office and local affiliates, notably Planned Parenthood of Maryland, have provided resource assistance to schools. PPWP proposes to establish a formal program of assistance to establish model programs in selected colleges of education and junior and senior high schools.
3. The Population Reference Bureau Inc., 1755 Massachusetts Avenue, N.W., Washington, D.C. 20036.
This organization publishes a newsletter, *People*, for teachers, researchers, and others interested in the population/environment field. The Bureau also issues bimonthly *Population Bulletins*, an annual *World Population Data Sheet*, and monographs, including *People* for junior high school students and *This Crowded World* for intermediate grade students.
4. The American Sociological Association, 1001 Connecticut Avenue, N.W., Washington, D.C. 20036.
Through its program, Sociological Resources for the Secondary Schools, it has published three units on population for use in secondary schools.

Grade Level	Social Studies	Science	Language Arts	Health	Home Economics	Fine Arts	Mathematics
3	Modern family no longer depends on many children as a labor force and old age security	An inquiry into family structure, size, and role in animal population	Supportive literature portraying happy small families, childless married couples, and even secure and contented unmarried adults	Assurance that immunization and other modern health practices provide child survival and longevity	An examination of the modern home providing comfort, privacy, and care for the small family	Studies of family art, possibly noting the current art of India depicting the small happy family	Story problem support to theme of greater individual wealth to members of the small family

Horizontal development of a population education theme in grade 3.

Grade Level	Science
4	The formal introduction of reproduction and sexuality using the flowering plants as vehicles in establishing a noncontroversial entree to the sexual reproductive cycles of organisms.
5	Plant population studies emphasizing biotic potentials and limiting environmental factors.
6	Reproduction in animals including studies of reproduction as a life process, sexuality as an adaptation, anatomy, physiology, behavior, mating, fertilization, development, biotic potentials, and parental care.
7	Human reproductive anatomy, physiology, and behavior—an upward extension of previous studies, coinciding as closely as possible with the onset of puberty.
8	Human population dynamics and the mechanisms of population control.

Vertical development of a population development theme. This sequence of science studies would be supported in other subject areas.

past several years a dozen or so organizations have addressed themselves to various tasks of instructional materials development. These projects include the preparation of bibliographies, the establishment of clearinghouses, and the production of instructional materials. Most of the action is being carried by international organizations for non-American audiences. A sample listing of organizations, and their activities, in population education for U.S. schools is on the opposite page.

POSSIBLY the greatest need in population education is the development of a comprehensive sourcebook. The sourcebook would identify and explicate a solid core of content and be not only a book of knowledge but also an anthology of ideas for the effective presentation of the content. The sourcebook would be useful to teachers who wish to incorporate population education into their programs. Coverage would include all grade levels and all subjects. The sourcebook would also be a fountainhead for the development of such instructional materials as monographs, films, and games.

The sourcebook may resemble in format the initial productions of the recent curriculum developments in biology and earth science, where content and curriculum specialists collaborated in brainstorming on the ingredient topics of the subject. In population education, for example, an anthropologist and a curriculum specialist in the social sciences could prepare jointly a section on the evolution of the human family, and suggest ways to communicate to children through educational media the modern trend toward the small family norm.

An overall curricular design for population education would have to be reflected in the sourcebook, even though the ultimate working structure of a program would emerge only after extensive classroom trials. As a beginning, we might envisage a curriculum grid that includes school subjects and grade levels.

For illustrative purposes let's trace, through a curricular grid, the development of two possible themes, one horizontally at the third-grade level and the other vertically through several years of science. In the first illustration assume that it was determined appropriate to concentrate during the third grade on the evolution of the small family norm. The study focuses in the social studies with other subjects providing support. In the second illustration, assume that the sequence of science studies, spanning the intermediate elementary school and junior high school, would be supported in other subject areas.

More important than the content of population education or its sequence will be the method by which it is learned. The phenomenon of excessive human population growth lends itself well to teaching and learning by inquiry. A teacher's mastery of this method will determine the ultimate effectiveness of his program in influencing his students in realizing objectives.

DESPITE intensive inputs into population control programs, world population continues to grow at the alarming rate of about 2 percent. The failure of these programs has been attributed to powerful cultural demands for high fertility. Efforts to influence acceptance of family planning means will fail until the attitudes of couples toward the small family norm overcome the traditional pressures for large numbers of children. New attitudes which will change reproductive behaviors can occur through the formal schooling of children in a program of population education. ☐

A PLAN FOR POPULATION-ENVIRONMENT EDUCATION

Robert W. Stegner

WE have been, and still are, witnessing an explosion of interest in population and environment education. Teachers searching for materials in these fields have discovered a flood of books, articles, and teaching aids; and curriculum developers are working to meet the need for planned programs of study. New courses of study are giving increased attention to "ecology"; and concern for pollution is general, extending even to the advertising of some of the greatest polluters, who know a public trend when they see one.

This long overdue movement is beginning to have some effect. Departments of Environment Control now exist in many states and Congress has passed an Environmental Education Act. All over the country, we are energetically attacking the *symptoms* of our problems. In dealing with poverty, we give money and housing; in dealing with water pollution, we clean up oil spills with shovels and straw; in dealing with air pollution, we require the use of low-sulfur fuels; to prevent war, we build weapons; to dispose of solid wastes, we fill up holes in the ground; to control crime, we hire more policemen; and to maintain our economy, we build the SST. All these actions can be justified—all can be criticized.

The author is associate professor of biology and education, University of Delaware, Newark, Delaware.

When a small creek flows through a partly rural, partly suburban, partly urban community, it sooner or later becomes a source of contention between those who demand the preservation of the creek for the sake of recreation, wildlife, and natural beauty, and those who see the creek as a source of water for continued "growth and development." These two factions usually are well defined. A third faction is beginning to emerge. These people, although perhaps not particularly concerned about the creek itself, are saying, "Don't build the dam!" They want to slow down and perhaps halt the endless spiral of growth and development which would be continued by the damming of the creek. They see that the additional water supply would inevitably result in the growth of industry and population, and they realize that there must be a limit. They say, "Let's take inventory and formulate a plan for maximum human fulfillment."

Whatever faction prevails at the moment, it seems clear that we must eventually reorient "rugged individualism" to include the welfare of the community and, indeed, of the species. The individual needs to understand how he can benefit from the reduction of poverty, hunger, pollution, and crime. The individual must see his stake and his role in solving social problems. If this understanding can be achieved at all, short of Malthusian limitations, it will be achieved through education of one kind or another, and surely the schools can contribute.

But our concern must go much deeper than the symptoms of our problems. In dealing with poverty, we must make it possible for people to attain self-respect through useful employment; in dealing with water pollution, we must have some understanding of biology, chemistry, industry, economics, and politics; in disposing of solid

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Figure 1. In order for our children to be able to understand and adjust to the complex systems in which they live, we must develop a K-12, multidisciplinary program of population-environment studies with a problem-solving approach.

wastes, we must eventually recycle usable materials; in maintaining our economy we must consider the natural system.

THE achievement of the individual's understanding of and adjustment to the complex system in which he lives requires a K-12, multidisciplinary program of population-environment studies with a problem-solving approach. These studies should be infused into the existing school program and should become a school-wide responsibility. Since an understanding of natural and cultural systems will involve every school discipline, we must have a comprehensive conceptual scheme to organize and articulate all the diverse components. Perhaps the theme of the Population Curriculum Study at the University of Delaware can serve as a base:

Man is part of a natural system, the Earth, and is ultimately subject to the limits of the system.

The development of this basic concept leads to studies of the properties and interactions of water, air, and the physical earth, which are already quite common in school science and geography courses. The development of the concept that *the earth is a finite natural system* may require only small changes of emphasis and orientation in most school programs, but these changes, although small, are vital.

While we are establishing concepts of the natural system and its limits, we must show that man originated in the natural system and that, although he often modifies and extends the system, he is ultimately subject to its limits. The uniqueness and superiority of man is so impressively obvious that it is difficult to establish his relationship to the natural system. Here we must have studies of human evolution, and we must clearly develop the relationships between physical structure and the uniquely human characteristics, such as erect posture, the large cerebrum, the opposable thumb, and binocular vision. And in these studies we must arrive at the evolution of a capability for culture. It is culture that gives mankind the power to alter the natural system, often to his advantage, but sometimes to the disadvantage of all species, including his own.

As human cultures have been applied to the environment, we have sometimes restricted the quality of life by our numbers and our activities. We must realize that sometimes human activities can lead to poverty, hunger, and pollution, and may deplete natural resources, degrade the beauty of the natural system, and distort human behavior. Without creating a concept of mankind as a destroying plague, we must bring ourselves face to face with our problems. We must dispel the notion that technology alone can continue, endlessly, to adjust a growing population to its environment. We must recognize that the control of population size can be a fundamental factor in solving human problems. Changes in life styles and technological management can sometimes alleviate pollution and upgrade human life quality, but eventually the control of the size and distribution of human populations will be essential in achieving a lasting adaptation of the human species to the earth. We must, sooner or later, realize that planning *within the natural system* can achieve a life of acceptable quality for all people and that herein lies our hope of freedom—freedom of choice of life style. The voluntary achievement of this goal depends on education.

A CONCEPTUAL scheme for population-environment education should include these basic concepts:

I. The earth is a finite natural system. (To show that there are limits.)
II. The evolution of the primates resulted in a capacity for culture. (To relate man to the natural system.)
III. The natural system influenced the evolution of human culture. (To indicate man's dependence on the natural system.)
IV. Cultural evolution led to dominance of the environment. (To indicate man's uniqueness and power.)
V. The activities of human populations

may lead to conditions restricting the quality of life. (For awareness of population-environment problems.)

VI. By planning within the natural system, a life of acceptable quality can be provided for all people. (To suggest some choices.) [1]

Each of the basic concepts of the scheme must be expanded to facilitate the assignment of responsibility for concept attainment among the teachers of a K-12 school system. For example, Concept V might be partly developed as shown in Figure 2.

In developing these concepts, there is a tendency for the subconcepts to accumulate excessively in grades 5 to 8. Placement of responsibility is not always clearly dictated because of variation in school curricula and organization. But the plan can be flexible depending on the local situation. The concepts listed for the middle school can go either way.

When the subconcepts are identified, materials for their attainment must be found in existing sources or must be developed for the use of teachers and students, and the responsibility for the attainment of the subconcepts must be distributed in a school district to faculty in appropriate subject-matter areas and grade levels. The teachers of a school district could read through the scheme, identifying subconcepts for which they are normally responsible or for which they would be willing to assume responsibility. Gaps in program responsibility could be identified by a coordinator and assigned to the appropriate teachers.

Since teachers already have plenty of work, ways must be found to include new materials without simply adding them to the work load. That could often be done by changing examples, applications, or emphases. In chemistry, time could be found for studying sulfur dioxide as an air pollutant by adjusting the amount of time spent on the manufacture of sulfuric acid. The fundamental principles of chemistry need not be neglected and the objectives of population-environment education would be served. [2]

V. The activities of human populations may lead to conditions restricting the quality of life.
  A. Human activities may lead to poverty and hunger.
    1. Human fulfillment depends on adequate nutrition.

Subconcepts for Grades K-4	*Subconcepts for Grades 5-8*	*Subconcepts for Grades 9-12*
People need food for energy.	People require a certain number of calories daily depending upon their activities.	
People need certain kinds of food for health and growth.	Malnutrition results when food is deficient in quality. (x)	Malnutrition affects one-half to two-thirds of the world's population. (y)
	Foods should contain proteins, carbohydrates, fats, minerals, and vitamins.	
	Protein deficiency is an important cause of malnutrition.	Amino acids are essential to man's health.
	Protein deficiency diseases are serious and often fatal for infants and pregnant and nursing mothers.	
		Cereal proteins are nutritionally less effective than meat proteins.
	Most of the world's protein foods come from cereal grains.	
	Malnutrition may cause permanent physical damage to growing children.	Malnourishment may cause irreversible damage to brain cells and other tissues.
	Malnutrition may cause mental retardation.	Mental retardation affects human fulfillment by limiting options for education, employment, and recreation.
Adequate food is necessary for work and play.	Malnutrition causes reduced disease resistance and lowered work capacity.	

Figure 2. Each of the six basic concepts must be broken down into subconcepts.

To implement these studies in schools, teachers will need a source book as suggested by Slesnick. [3] A subconcept in the conceptual scheme should have a code relating it to various sources of material in the source book. For example, the subconcept "Malnutrition results when food is deficient in quality" would refer to page (x) in the source book which would contain a definition of malnutrition and undernutrition, descriptions of the symptoms of kwashiorkor, marasmus, etc., and a discussion of the qualities of various foods. The subconcept "Malnutrition affects one-half to two-thirds of the world's population (y)," refers to (y) in the sourcebook, which would contain a map depicting the levels of nutrition in the world's peoples. The source book must also contain bibliographies and lists of films and other teaching aids such as maps, models, games, and equipment.

The expanded conceptual scheme, with the source book, will be the essential components of a K-12, multidisciplinary program of population-environment studies which can be infused into existing school programs without disruption. [2] The expanded conceptual scheme could also be a syllabus for a separate course. Such a program will have a potential not only for the attainment of the goals of population-environment education but also for an unprecedented articulation of the entire curriculum. ☐

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ARE WE AS ONE?

R. Thomas Tanner

THE editor suggested that in this article I might "show teachers how they can help to develop insights into the interrelationships of animals, vegetation, and man, and perhaps describe how these insights arise from increasingly deepened and sophisticated concepts that students gain as they mature and go along through school." She has also given me leave to develop an alternative idea if I so please. Following her lead, I should like to devote the first portion of this essay to the "hows" which she has suggested, and then turn my attention to the "whats" —the insights and concepts to be developed.

First, regarding the "hows," I can offer only a most general statement, based primarily on my personal experience as a learner and a teacher: Field activities of the right kinds are marvelous vehicles for the attaining of those concepts and insights we deem desirable. "The right kinds" include activities by which learners become rather intimately familiar with the biota of a limited area over a considerable period of time. I have no idea what the range of size and the characteristics of such an area might be, especially in the urban-suburban complex. In my own most fortunate youth, the area was a varied riverine-swamp-orchard-pasture-cropland complex some two miles square, and the period of time was some ten years of childhood and adolescence. The intensity of study was enhanced, not incidentally, by the fact that there was no automobile in our family during my adolescent years!

"The right kinds" of activities, I would further conjecture, include an occasional sudden plunge into a dramatically new environment. Many of our readers will have experienced the satisfactions and surprises of providing the first experience of ghetto children with a farm, inland childen with the seacoast, or lowland children with the mountains. There is a very real and unanswered question, I think, regarding the optimal frequency and age at which such encounters should occur. I became "hooked" on the Oregon desert upon first encounter. But this encounter did not occur until age twenty, and prior to this time I had never been more than 200 miles from the area mentioned above and had ranged that far only rarely and briefly. Social critics have noted the superficiality of the contemporary American experience—we see all the national parks, but see none well; we visit all 50 states, but feel close to the earth of none. At the risk of generalizing from the self, I would hypothesize that the intimate knowledge of a circumscribed area might best precede or at least coincide with experiences that are more geographically far-flung. This does not mean that the very well-traveled child will fail to attain the insights and concepts we seek, if his parents are wise enough to intensify his experiencing of each place visited and if some of his teachers do the same.

"The right kinds" of activities include also, I suspect, a good many which the learner experiences alone and a good many others which he experiences with one or two friends. If his *only* field work is in groups of 30, the experiences are bound to be superficial. The implication for field work is direct: Give field assignments which are "homework" in nature and which cover a rather extended period of time. As a high school teacher, I found that the single activity to which students were most "turned on" was an ornithology assignment handled on a contract basis. ("I verify that I have spent *X* hours in the field and have identified *Y* species of birds along with *Z* species of mammals, reptiles, amphibians, and/or fishes. Therefore, according to the terms of the contract, I request a grade of — for the field work.")

I suspect also that "the right kinds" of activities are interdisciplinary, either internally or in their association with other activities: the field trip which encompasses geology, natural and human history, agriculture, and industry; the science field trip followed by classroom reading and creation of humanistic expressions in the form of painting, poems, sculpture; the team-taught "regional studies" course.

Finally, for all our contemporary and well-placed concern for holistic, conceptual learning, tidbits of specific

Dr. Tanner is an assistant professor at Oregon State University and is the director of The Rachel Carson Project of the Corvallis Public Schools. He is also a member of the NSTA committee on environmental education.

information which are simply *interesting* are motivational vehicles in any study, including field inventories.

SO MUCH for the "hows," and on to the "whats." What should be the insights and concepts which learners acquire regarding the "interrelationships" of animals, vegetation, and man? I shall not try to distinguish between insights and concepts, nor imply that those given here are either inclusive or exhaustive. They are, rather, suggestive of a general set of insights, concepts, beliefs, attitudes, emotions, and commitments that I feel are mandatory of our citizenry. We shall begin with several which fall in the cognitive domain, followed by several which are more obviously of the affective domain.

Man is a poor dominant. Rappaport [7] develops the idea that anthropocentric ecosystems, those of man's devising, demand extreme inputs of energy and materials in order to be highly productive. A monoculture, be it a lawn or a wheat field, is difficult to maintain, especially if it is of an exotic species. Indigenous polycultures require no inputs from man. They are dominated by one or a few species of plants which dominate by their mere existence. Man dominates not by existence, but by action. Some action is mistaken, and some mistakes threaten the long-range existence of the anthropocentric monoculture. Some *big* mistakes even threaten the subsequent succession of the indigenous polyculture. I am not suggesting that we abandon agriculture; my point is that man must dominate *less* of the earth and retain *more* sanctuaries of indigenous polyculture and thus more margin for error. The secondary implication regarding human numbers is obvious.

Research on endangered species is not sufficient to save them. There is a peculiar bias in technical articles and in the mass media alike. A presentation, be it on whales or eagles or whatnot, often concludes with a statement implying, to the unwary, that all will be well because research on the organism is being done. Thus are powers beyond its capacity seemingly ascribed to the process of research. The recipient of the communication must understand that the first priority is to curtail certain or all incursions upon the species, lest there be nothing left to study.

Tomorrow's technology may not be able to undo the legacy of today's mistakes, regardless of whether the mistakes resulted from avarice, ignorance, or reasonable risk-taking. Extinct species cannot be restored by presently imaginable technology.

Biocides (insecticides, herbicides, antibiotics) will over the long haul tend to select in favor of species having high fecundity and numbers (cockroaches, microbes) and against species having low fecundity and numbers (mountain lions, eagles). Enclaves relatively free of biocides are necessary.

And, I have wondered, for I have not found time to check with a population geneticist, whether the following might not be true: *Species recovering from a very small number (e.g., fewer than thirty whooping cranes) are operating with an extremely restricted gene pool,* offering limited genetic variability for future adaptability. If this is correct, the implication is that species must be thoroughly protected long before their numbers become so small.

THE remaining ideas are more clearly placed in the affective than in the cognitive domain, though in some cases the domains are inseparable. Also, some have as much to do with methodology (the "how") as with the attitude or belief (the "what") to be gained by the learner.

Undesirable attitudes toward nature and our fellow creatures may be transmitted quite innocently. For instance, a recent television program described the capture of a jaguar with no hint as to why it was captured. This omission implies that it is permissible to manipulate members of other species at our whim, without good cause. In an article a few years ago, Richard Haney [4] questioned the use of dissection and animal experimentation in the classroom. Just what are we *really* teaching our students about our relationship to nature, Haney asked, when students perform deprivation experiments or watch the teacher perform a vivisection. As a traveling science teacher a decade ago, I vivisected some 70 or 80 each of rats and salamanders, and some 30 turtles, in one school year. Although this provided rather impressive demonstrations of working cardiovascular systems, I am not at all sure I would do that again, as I consider the lessons that may have been inadvertently taught.

The world of nature provides one of the great sources of interest in a world becoming overly developed, homogenized, and artificial. There is much truth in the old saw that variety is the spice of life. Man's activities may *increase* variety up to a point, by offering urban-suburban experiences to the already rich array of experiences offered by the natural world. But beyond that point, man begins to *decrease* variety by "rolling up the rug behind himself," that is, by exterminating species, eliminating wild areas, wiping out older cultures and rural communities. Man would be well advised to maintain diversity; the implications for economic growth and population growth are obvious. This esthetic, or affective, argument for diversity has been made by Dasmann [3], Mishan [5], and the present writer. [8] We might also note the strictly functional, or if you will, cognitive, rationale for diversity. Many ecologists tell us of the stabilizing influence of complex ecosystems, rich in species, full of checks and balances, and with great potential for survival under changing conditions.

Interestingly, Toffler [9] proposes that America maintain varied patterns of human life for similar reasons. Toffler would have enclaves of the past, rather like Williamsburg, Sturbridge, or Mystic, but involving many more people who retain skills of yesteryear. There would be highly experimental enclaves of the future, also. Residents of both would be reimbursed by government. Then, should the mainstream of culture fail, other ways would be available. How utilitarian, and how esthetically pleasing as well!

Love of the natural world. This "objective" lies clearly in the affective domain; it is definitely a higher order objective. In fact, it is the highest order objective. I can express it less prosaically but no more clearly than that: "love of the natural world." This is the love, blended in the maturing individual with rational intelligence, which views *every* encroachment by man against nature as an act to be entered into with only the greatest reluctance and only when every conceivable alternative has been fairly and honestly weighed and found wanting. This, it seems to me, must be the core spirit of a people aspiring to live at peace with the planet. From a people thoroughly imbued with such love should flow, with relative smoothness, the solutions to many specific environmental ills that would otherwise be viewed piecemeal and treated superficially. And this brings us to the final one of these examples:

Appreciation of our predecessors' wisdom and love. I said earlier that interdisciplinary field studies, including both human and natural history, might best be expected to accomplish the kinds of objectives described in this article. The human history can and should include the relationship which the former, preliterate residents had with the land, a relationship whose profundity, both cognitively and affectively, is currently enjoying a minor wave of recognition in our culture. We may note that the ancient fireside tales of the Klamath Indians accounted for the formation of the Crater Lake caldera in precisely the same way that contemporary geologists do. [1, 2] This wisdom of the Klamaths can, of course, be ascribed to simple observation. More profound is a traditional Eskimo creation tale, as related by Farley Mowat:

> It is said that Kaila, the God of the Sky, created the Eskimo and gave him the caribou for his sustenance. The Eskimo hunted only the big, fat caribou, for they had no wish to kill the weak and the small and the sick, since these were no good to eat, nor were their skins much good. And, after a time, it happened that the sick and the weak came to outnumber the fat and the strong, and when the Eskimos saw this they were dismayed and they complained to (Kaila, the God of the Sky, saying): "Your work is no good, for the caribou grow weak and sick, and if we eat them we must grow weak and sick also."
>
> Kaila heard and he said, "My work *is* good. I shall tell Amorak, the Spirit of the Wolf, and he shall tell his children, and they will eat the sick and the weak and the small caribou, so that the land will be left for the fat and the good ones."
>
> And this is what happened, and this is why the caribou and the wolf are one; for the caribou feeds the wolf, but it is the wolf who keeps the caribou strong. [6]

I consider this story with awe and admiration. Today, game biologists continually reconfirm the Eskimo's insight and try to get the rest of us to understand, whether the subject be deer on the Kaibab Plateau or gazelle on the Serengeti Plain. But the Eskimo already knew and understood. He already understood much when the Vikings sighted Cape Cod. He already understood when man-made wings took to the air at Kitty Hawk. He may have still known and understood when Neil Armstrong's boot touched lunar dust, though by this time we had taught him to forget much. But when Eskimos related this creation tale to Farley Mowat, several decades ago, they still understood. Millennia of intimate contact with a relatively simple environment had isolated for the Eskimo a limited set of phenomena as surely as Mendel isolated the traits of his garden peas, allowing the Eskimo not only to observe, but to reach a higher order generalization anticipating that of Darwin himself!

In those same millennia, Western man bolted headlong into successive environments which he discovered, created, and re-created faster than he could comprehend them. His evolution upon the earth made of him an epiphyte: He left behind the roots that once had bound him to the earth. "The Roots of Heaven," Romain Gary called them. Garrett Hardin called the process "extrasomatic evolution," referring to the physical extensions of ourselves which we call the auto, the aircraft, the computer. Hardin was saying that extinction can follow overextension, overspecialization. Don't cut off your roots completely. That is what Toffler is proposing, with his enclaves of the past. A century ago, Chief Joseph of the Nez Perce said something like this: The earth is my mother. You tell me to remove the stones from the earth. I would not remove my mother's bones. You tell me to plow the earth. I would not cut my mother's breast. You tell me to sow strange grasses, and then cut them off. I would not cut off my mother's hair.

Joseph had deep roots. Western man has rushed ahead, re-creating new environments, forgetting old ones, cutting his roots. To his servant, Science, he has assigned the task of studying what he now calls "nature."

And now, as the heavens whirl inexorably about the pole star, Joseph speaks to us as from distant galaxies: His earth may have died before light reaches us. The hardy, thrifty zerophyte calls to the epiphyte, "Beware, lest your host tree die of your demands upon it."

Perhaps we are beginning to listen . . . enough . . . that one day our posterity, who will have long forgotten the records of our individual and national vanities, will remember of us only that it was we who said to the God of Science, "Your work is not good." And the God of Science replied, "My work *is* good. I shall help Man to rediscover the earth and live with it." And that is why Man and the earth are one. ☐

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Conservation Education: Problems and Strategies

HAROLD R. HUNGERFORD and CLIFFORD E. KNAPP

Instructor in Science Education and Instructor in Outdoor Education, Respectively
College of Education
Southern Illinois University, Carbondale

CONSERVATION education is the process of helping human beings clarify their personal values concerning their environment and subsequently make decisions about its use.

The goal of conservation education ultimately lies in producing an *active conservation-oriented citizen. Active* describes an individual who is personally *involved* in decisions and practices regarding resource use and management; *conservation-oriented,* one whose values are sympathetic to responsible resource use and management.

The belief that the learner should demonstrate conservation-oriented behaviors is supported by an examination of society's major environmental problems and issues.

> . . . We seem to have crossed a threshold in terms of population and industrial development and entered a period in which the fouling of air, water, and landscape has reached critical dimensions—critical for health, both physical and psychological, as well as for decent and pleasant living. [1]

This article is based on a paper presented at a contributed papers session of the 1969 Convention of the National Science Teachers Association in Dallas, Texas, on March 22.

Man has failed in his obligations to himself and future generations in his handling of specific resources. Because conservation should be everyone's concern, the schools of the nation have a tremendous responsibility. Society's institutions (mainly the school, family, and the church) are not meeting this educational challenge fast enough. Tensions do exist between intelligent action in resource problems and expediency, selfish profit motives, and political pressures. Also, man is often motivated by his emotions rather than by reason and logic; and most citizens are extremely apathetic about the environmental decisions which affect their future lives and the lives of their children. In our democratic society, individuals *must* realize that they *can* and *should* influence conservation decisions. Furthermore, they must realize that decisions must be made using the most current and accurate knowledge of ecology and sociology.

Problems:

The magnitude of the problem.

> Because of the great abundance of the earth's resources we have taken them for granted. But now, over most of the globe, . . . we are face to face with a serious depletion of "resource capital." More than one country is already bankrupt. Such bankruptcy has wiped out civilization in the past; there is no reason for thinking we can escape the same fate, unless we change our ways. [4]

These words of Bernard M. Baruch are much more than platitudes. They represent, in light of today's pressing resource and population problems, perhaps the most accurate appraisal of man's ecological position.

In light of the severe conservation problems facing the world, it is important to give children an opportunity to form and clarify values and make decisions which will have a direct bearing on their ability to function as rational adult citizens. It is our belief that this *can be done,* but it is going to take a strategy far different from that which is currently in operation in most classrooms around the country.

The assignment of responsibility for conservation education. Historically, conservation education has been the responsibility of every elementary teacher and the science and/or social studies teachers at the secondary school level. This unwieldy circumstance may be part of the reason why conservation education is usually ineffective. Elementary teachers either ignore the task completely or are unable to define their role in terms of content and methods. At the secondary school level, the science staff is usually unaware of what the social studies teachers are doing and vice versa. Both groups of teachers are probably not too successful because conservation is actually a scientific-technological venture with gigantic social ramifications, and teachers are usually not able to deal effectively with these interrelated concepts.

The apparent unconcern for education for values. Conservation definitely involves value-oriented decisions about how resources are to be used. Do we set aside a hardwood forest as a preserve because of its ecological significance, or do we harvest the marketable timber and manage it for commercial purposes? Or, going one step further, do we subdivide the land for real estate purposes?

These are the kinds of questions being answered all over the United States today, sometimes satisfactorily and sometimes with disastrous results. These kinds of issues must be appraised by students in the classrooms in order to establish a set of values in accord with human welfare and a quality environment. Little practice in doing this can be observed in schools today.

Incorrect, incomplete, and oversimplified resource concepts.

> Of utmost importance to all facets of the world in which we live is for man to know that the physical-biological world in which he lives is governed by scientific laws which are as strict in their discipline as any ever formulated for any purpose anywhere. The natural world is an orderly world, providing its own checks and balances to keep the very necessary elements of the environment under control. Thus done, the whole picture is relatively stable, nature being able to replenish itself indefinitely. Man's role in the world of nature is of tremendous importance because man is the one organism (and the only one) capable of doing irreparable damage to nature. The human organism, because of his ability to "control" the environment, holds the future of the natural world in his hand. [2]

If conservation is the application of knowledge and values to resource-use problems, then the successful solutions to these problems rest with the extent and accuracy of the knowledge that students have about the resources in question. Decisions are based on the alternatives available. How can students possibly make decisions without appropriate knowledge? A tremendous abundance of literature on resources exists. It must be carefully screened for accuracy and modern application. The careless choice of available conservation information is another reason why conservation education is ineffective today.

Many of the important conservation issues today are those that reflect inadequate information. Concepts dealing with ecology and resource management will often change over time. Currently, for example, we must make tentative decisions about the use of pesticides without complete information about their effect on the biotic community. We do not know the total effect of city noise levels on mental health. We can only hypothesize about the effect of carbon dioxide from internal combustion engines on the climate of the future. Man just does not have all the answers. When survival and continued prosperity are in question, and there are still so many unknowns, the task of conservation decision making becomes difficult.

Deciding whether to place telephone lines underground in order to improve the view is a far cry from deciding on the question of the ultimate need for legislating human reproduction. Still, it may be quite important for students to judge the value of underground wire installations. At this point in time we have no accurate concept of the role of visual stimuli on the total welfare of the human organism. Tomorrow we may find this of critical importance. Similarly, our values regarding legislation concerned with controlling human reproduction could be a far cry from those values generated in a population double what it is now, possibly in another four decades. Knowledge and values do change and we must learn to cope with this situation.

Little opportunity for students to practice conservation. Conservation education, where employed, is usually quite abstract and detached from the day-to-day existence of the individuals in the classroom. Even where role-playing devices are used, the values obtained and the decisions reached are often simply vicarious and artificial. To be successful in clarifying values and to aid in decision making, conservation education must somehow enter more fully into the real world of resource use and management. Any value held by any individual must carry with it three characteristics. [3] It must be freely chosen from alternatives available after careful consideration of the consequences of each alternative. It must be prized by the person holding it so that he is willing to publicly defend it; and perhaps most important, a value must be *acted upon repeatedly* over a period of time. Little opportunity exists for human beings to do this in the traditional plan for conservation education. A person forming attitudes in the classroom is not committed to them unless he has an opportunity to translate them into action. The student, therefore, must subject his values through decision making to the pressures of peers, the community, and society.

Strategies:

It appears to the authors that there are four basic strategies which are necessary ingredients in a conservation education program.

Determining the teaching responsibility. A developmental program of conservation education is mandatory for ultimate success. In certain states this strategy has already been legislated even though legislation may be an ineffective means of accomplishing the desired end.

Conservation education is often said to be the responsibility of all educators, and certainly this may be true in theory. However, responsibility must be assigned so that a program can be planned and progress can be measured. The teacher of the self-contained classroom is the key person at the elementary level. Regardless of how many resources the teacher uses, he must still be ultimately responsible. The secondary school classroom is another problem. If the task of conservation education is to remain a function of both science and the social studies, then both *must communicate* and *work together* toward *mutually acceptable goals.* In fact, this may be the best means of establishing a conservation education program that appropriately reflects both the scientific and social dimensions of the resource problems facing society.

Developing correct and complete concepts. In order to apply the knowledge necessary to solve problems, the students must understand a great deal about the world in which they live. Scientific data must begin to take on meaning in a social context. The student himself must conceptualize the problems of air pollution, for example, to a point where he can predict with some degree of accuracy the eventual effect on himself, his offspring, and other living organisms. And, this is really only the first step . . . a conservation-oriented action is eventually needed.

The goal for conservation educators must be to provide the student with a set of experiences in and out of the classroom that will guarantee that he really does have the concepts he needs to make effective decisions.

Providing student practice in decision making. Conservation decisions are made on the basis of convenience, beauty, economics, physical comfort, or other needs and desires of man. At best, the conservation educator can only raise questions in the student's mind. The student himself must ultimately make conservation decisions based upon his own values. The teacher can make known his own stand on specific issues, but the process of clarifying values in terms of alternatives ultimately belongs to the student. The important thing is to give the student an opportunity to analyze alternatives in light of known information and his own value system.

Testing values through action. If a youngster is to become an active, conservation-oriented citizen he must have experiences throughout his school life which produce concepts and values about the world in which he lives so that he can make decisions regarding the use of natural resources.

It follows that these decisions must be, at least in the beginning, of a very personal nature. The "pay-off" must be as immediate as possible so that the student can see the consequences of his decisions. If he wants to increase the bluebird population then he must build bluebird boxes, install them correctly, and analyze the results. If his seventh-grade class wants to study certain elements of forestry management, then they might plant an acre of pulp trees, care for them throughout the next six years, study the ecological factors involved, and harvest those trees when they are seniors. If Mr. Johnson's pond is full of stunted fish and the students want to do something to bring about a more balanced fish population in that pond, then they should secure permission to poison that pond, restock it, and conclude with an ecological study of the project. If they are legitimately concerned about open sewers dumping raw sewage into the local stream, then they should launch a campaign to get the situation corrected.

These things are real. They are part of the lives we lead as citizens. They have a "pay-off" value for students in school, and they may solidify values which will last a lifetime. The student must move from the status of a bystander without personal involvement to the level of a participant with total involvement. He is now a defender of values and a decision maker, and he must face the results of his decision making. No longer is it just talk; it deals with the real world and he is personally involved. He will be involved for the rest of his life as an active, conservation-oriented citizen. This is what we must attain despite the educational problems involved!

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A new NSF-funded project focuses on self-awareness and the environment

ENVIRONMENTAL STUDIES

Robert E. Samples

The job of Environmental Studies is to create instructional tactics and strategies that will enable students to use their immediate environment as a resource. Three environments are considered. The first is the inner environment of the child. The second is the immediate environment in which he finds himself, and the third is the global environment. Left, third-grade students from Bedford-Stuyvesant, Brooklyn, New York, leave school to investigate their neighborhood.

Mr. Samples is a director of the Environmental Studies Project of the American Geological Institute, located in Boulder, Colorado.

AN ARTIST is a person who works within the constraints of the medium in which he has chosen to express himself. In addition, the artist becomes a creator when he makes his medium extend itself beyond the uses found by others. The Environmental Studies (ES) project, recently funded by the National Science Foundation, is an effort to allow students the opportunity to work in the most exciting medium available—the environment—and to become creators by using the environment in ways that most never dream of.

Working with the environment does not require the student to study it in any particular way; instead it invites intellectual and emotional involvement. As the student becomes involved, he must make decisions—his own decisions. Through involvement and decision making he can experience accomplishment. These are the concepts upon which the Environmental Studies project is based. The focus of ES encompasses *everything* in a student's environment, whether it falls into the category of physics, grammar, or art. And the methods through which the students can study are as varied as the students themselves. Instead of being rewarded for their acquired abilities to conform, students are rewarded for their diversity.

The vehicle for bringing about the student's involvement with his environment is an intentionally ambiguous assignment. For example, armed with Polaroid cameras, students in test centers in New York, Washington, D.C., Chicago-Gary, Los Angeles, San Francisco, and Denver swarmed out of their classrooms to photograph the motion of the sun, rusting cars, chipped paint, blooming plants, and despondent people: all this in answer to the assignment, "Go out and photograph evidence for change."

The assignment allowed the creative use of the medium, the environment. The students were given an assignment in which they had to make decisions. They were not told which examples of change to photograph. As a result, they found dozens of changes instead of just a few. They chose the content they wished to portray and then mediated the portrayal of it. The content they chose was change in the sky, in bricks, in the plants surrounding the school, and even in the teachers. The students were working with reality and it is that involvement which keeps ES alive in answering the needs of the students. In the sciences and arts, men focus their skills on the unknown; similarly, in ES, the students focus their talents and skills on the unknown in their own environment. They confront reality and realize the potential of their talents. In this way, the students study in a fashion similar to that of the experts in the field.

The Polaroid cameras in the assignment were utilized specifically to create an environment for success. Most of the students with whom the ES materials were developed were in the inner cities. Alerted to the findings of hundreds of studies concerning inner-city students which indicated that these children lacked a sense of accomplishment, the developers of ES used the instant photography potential of the Polaroid camera to provide success or failure in just ten seconds. Although most of the assignments in the materials do not require the use of photography, all can be enhanced by it.

ENVIRONMENTAL Studies has thus far produced Packets 1 and 2, each consisting of 25 assignment cards. Packets 3 through 6, also consisting of 25 cards each, are being developed.

As students examine their environment closely, they first develop an awareness of its components. Next, repatterning takes place as they compare old or latent awarenesses with new ones. The final step in the intellectual involvement of the students with their environment, or the extension phase of their involvement, is the invention of more abstract ways of explaining what they see and feel. The first two ES packets concentrate on heightening the student's awareness, the second 50 cards are planned to provide guidance in the repatterning phase, and the final 50 will focus on extension activities.

The format of each assignment card is designed to encourage inventiveness in the teaching-learning environment. On the front is a visual metaphor of the characteristics of the assignment. On the back is a section called "The Action," which gives the primary assignment. Sometimes examples of the kinds of things which the students can do to fulfill the assignment are included. In another section called "More," extension or secondary assignments for the teacher to use at his discretion are found. Pedagogical comments to the teacher are printed at right angles to the rest of the text. These are hints and warnings that help the teacher keep the assignment open to ensure that the students are doing the majority of the decision making. The final feature of the card is the space left for note taking, which invites the teacher to jot down an abbreviated diary of what took place.

Ninth-grade students in Aruada, Colorado, induce erosion in order to determine the most effective ways to prevent it.

Since they are designed to be used by teachers at their own discretion, the ES materials are not a curriculum. Many teachers are using the materials along with existing curriculum programs. Others are basing their entire year's activities around the exploration resulting from the assignments. The materials are nondisciplinary and, since they are written for the teacher, they can be used at any grade level. Although their use in grades K through 3 has been limited, the teachers using them at these levels have reported success. The program is inexpensive in that the only special materials so far required are Polaroid Swinger or Colorpack cameras. The cameras and film for a class cost far less than the materials for many other programs. The support equipment and supplies are generally available in schools. The materials were designed to serve existing teachers and existing facilities and need little else for successful use.

When the writers gathered in Boulder, Colorado, in late summer of 1970 to develop the first 50 cards, they tentatively wrote them within the four categories: change, mapping, counting, and judging. However, near the end of their duties, they criticized the four categories as being just as artificial and restrictive as the specific content categories in the earlier curriculum project efforts. Thus, the categories were eliminated. An "anti-guide" labeled "ESSENCE—ES sense" was written to assist the teacher in developing an awareness of the attitude shift that is necessary for the use of the ES materials.

In nearly 20 meetings at which the materials have been introduced, the teachers have reacted similarly. They see a challenge. Neither the assignment cards nor the teacher's booklet provides a recipe for their use: The teachers are given as much freedom to make decisions as it is hoped they will give to their students. In the face of the suggestion that they trust students, the teachers themselves are trusted. The teachers are accepting with excitement the challenge and the trust. The preliminary results of the materials are heartening.

For further information and Newsletters detailing the progress of ES, please write to Environmental Studies, Box 1559, Boulder, Colorado 80302. ☐

ECOLOGY AND THE URBAN STUDENT

DONALD F. SHEBESTA

MODERN TECHNOLOGY has enabled man to control and improve his environment with some degree of success. To the degree that he can alter the environment for his benefit, man can escape natural controls. By technological structuring of the environment, urban man has become less aware of his ecological relationships and, therefore, less likely to consider the consequences of his environmental manipulation.

If changes in the ecosystem are made for man's benefit with little concern for the ecosystem, disaster can result. So far, we as a species have been able to survive man-induced detrimental changes in our ecosystem—but what are our tolerance limits? Man circles the planet in a matter of hours; he is dependent upon materials from around the world; he exploits natural resources and wildlife, pollutes waterways and air; increases his population in a geometric proportion; and allows his cities to ooze out in one sprawling megapolis after another. His activities, technology, and demands affect his ecosystem throughout the entire globe. Man's ecosystem is in this sense the ecosphere.

Awareness of this scope of ecology is not inborn; it is learned; and it must be learned. Such an awareness is necessary so that man can understand what goes on in an ecosystem and can bring about beneficial changes without endangering the system.

Urban high school students need opportunities to discover the application of ecological principles in real life as well as in the abstract. These students lack an orientation toward rural situations to which most ecological studies refer. They are familiar almost entirely with a man-made environment, and learning, therefore, needs to be set in that environment if the learning is to be relevant to the pupil and to the society in which he lives.

Mr. Shebesta teaches biology at West Division High School in Milwaukee, Wisconsin.

Ecology in the urban school must be oriented toward the urban student who will be functioning in an environment that is to some degree artificial and increasingly man-made. The student must gain an understanding of his environment before he can fully participate in it. The better his understanding of his environment, the less likely he is to destroy it—and the more able he is to improve it.

The urban student is visually oriented, but he needs to develop his powers of observation, manipulation, and contemplation. He needs to be shown or to explore through concrete examples, actual or artificial, how principles operate and from this base move into the realm of abstraction. The urban student is familiar with the city, but he may or may not be aware of the effect of this man-made environment on its inhabitants. Ecology is a valuable central theme for the student's study of man's relationship to the environment.

The curriculum should be relevant to the society in addition to being relevant to the student. The society in which the student lives also demands a system of ethics that he must know and abide by. If value conflicts arise—as is often the case in ecological situations—we must show the student how to resolve such conflicts.

For years, many of us have assumed that putting the child in school at an early age takes him out of his natural environment and puts him in a contrived setting. Only recently has our understanding of the ecology of human living and the nature of man's relationship to his technology clearly forced us to realize that the choice for education of young children is not between a contrived and natural environment but between a planned and a haphazard man-made environment.

The student must be given situations in which he can participate, but this need not be entirely field or laboratory oriented. Nor is it necessary for an urban ecology course to replace the

PALEY PARK, NEW YORK CITY

present general biological studies. Ecology should become an integral part of the science curriculum at the urban school. It should be a relevant subject, dealing with topics such as pollution; birth control; urban development; energy and nutritional systems in an urban situation; population density, regulation, and diversity; control of environmental stimuli; and the ecosystem concept. Students can participate through a variety of planned activities, such as discussions, research, and reports, in addition to laboratory and field work. The type of work should reflect each student's individual abilities, the number of students in the group, and the general ability of the group as a whole. All work should be directed to develop responsibility within the student and to bring the student into contact with ecological principles and their application to his environment. We must see ourselves and the student as self-directed, self-actualizing, creative, other-sensitive, problem-solving, positive-value-possessing individuals.

The following two examples of this approach have been quite successful with my students in a large city.

THE NUTRITIONAL SYSTEMS concept is approached from the standpoint of establishing a lawn. The students are given a choice as to whether they wish to begin with seed or sod. They are requested to develop a procedure to establish a healthy lawn. I do suggest to them that they consult with a garden center and write to or obtain information from fertilizer and lawn seed companies. (Such information will usually be supplied to teachers in sufficient quantities for a class if requested.) This inevitably leads to a discussion of the necessity of fertilizer.

The students are then assigned to acquire information concerning various fertilizers. They are to record the brand name, quantitative and qualitative contents, trace elements, particle size, rate of availability, and price. This information is given on the bag containing the fertilizer. A chart is then made, listing this information by brand, and the students compare contents and prices. These comparisons lead to a discussion and demonstration of the need for the various minerals and why fertilizers are used. We generally conclude this section by including a soil profile of a typical area around the school and requesting students to bring samples of soil from near their homes. The students test these samples to determine what nutritional requirements need replenishing in each sample and select an appropriate fertilizer.

The topic of fertilizers is also used to develop the idea of the recycling of nutrients. The sewage in our city undergoes primary and secondary treatment and is processed into a commercial fertilizer. We cite this process to help demonstrate decomposition of organic material and conclude on the biological and economic value of this product. In this study, most students find out for the first time what happens to their personal waste products.

A PROBLEM on monocultures was triggered by an actual situation that developed in the trees of our city, where the streets were lined primarily with elms. In the past years, Dutch elm disease has devastated the elm population in this country. This year the disease took its toll of the mature, arching elms surrounding our school, and the trees had to be removed. The students felt ill at ease because of the starkness of the treeless environment.

Using this situation as a starting point, we began talking about the esthetics of the lost trees. This developed into a discussion of the reasons for their removal and a study of Dutch elm disease. This study showed us that the density of the trees aided the spread of the parasite. We then attempted to present proposals that would prevent this from occurring again. The suggestions that were most frequent were: (1) use a variety of kinds of trees, (2) develop disease-resistant trees, and (3) space the trees farther apart.

Two tangents naturally developed from this. First, what kinds of trees should be used? The students began by stating their preferences or guessing, but they generally avoided naming the elm. Upon development of the ideas, they began to realize that they were not the only ones affected by this problem. The same problem faced the whole city. The students investigated the cost of trees, the availability of various kinds, problems in planning, and in satisfying the people in front of whose homes new trees might be planted. They gathered most of their information by using nurseries and the city forestry department as resources. Next, they discussed educating the citizens to care for the new trees so that they might supply the cover and esthetic qualities once possessed by the area.

OTHER CITY SCIENCE AREAS that I hope to develop are: wildlife in an urban situation—where and why does it exist; population and behavioral studies utilizing human and animal populations; wild domesticated animals; alley ecology; energy transfer systems needed to operate a city; air, water, and thermal pollution; waste disposal problems; the planning, creation, and study of recreation areas; approaches to dealing with water run-off problems; and urban development. This list could probably be extended indefinitely to include examples for many aspects and principles of ecology. The local newspaper carries many articles which point out problems of ecological value currently concerning cities. We need much more material that is relevant to the urban student.

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More Than a Forest

CHARLES O. MORTENSEN

PhD Candidate
Environmental Education
University of Wisconsin
Madison

Students building a nature center under the supervision of the industrial arts instructor. All buildings, including dormitories, have been constructed with lumber sawn from logs cut in the managed portion of the school forest.

WITHIN the rolling, unglaciated portion of South Central Wisconsin lie 278 acres of oak-hickory: the Madison School Forest.[1] The Society of American Foresters' book on *Forestry Terminology* [2] defines a forest as a plant association predominantly of trees and other woody vegetation. Madison's Forest easily meets these criteria and many more. It has, among other things, a director, a naturalist, a unique staff of part-time naturalists, and the often familiar trails, signs, and buildings. Yet, it is not only these things, important as they are, that separate a school forest from just any forest. The uniqueness of a school forest lies not so much in how we define it, but rather in how we use it and to what ends. Our forest offers special opportunities:

Observation and Learning. Perhaps above all else the Madison School Forest offers an opportunity to observe and learn or rather, in the vernacular of today's youth, a chance to see "what the action is." Those who have seen the brightening eyes of young children as they experienced for the first time such things as the plaintive song of the black-capped chickadee, the put-put drumming of ruffed grouse, the unique curved hooks on the seeds of burdock, or the long bole of a tall black cherry will attest to the stimulation provided by observing forest life. But, do children really need to hear the trill of a toad or see pin-sized eggs on a stalk, or even think about their part in the whole? The answer is yes—and not just for the children, but for all of us. Perhaps we will then see and think about more than meets the casual eye, beautiful as it is. Aldo Leopold stated it clearly and succinctly:

> . . . sit quietly and listen . . . and think hard of everything you have seen and tried to understand. Then you may hear it—a vast pulsing harmony—its score inscribed on a thousand hills, its notes the lives and deaths of plants and animals, its rhythms spanning the seconds and the centuries.[3]

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[1] Officially renamed the Col. Joseph W. Jackson School Forest, Madison, Wisconsin.

[2] Meyer, Arthur B., and F. H. Eyre, Editors. *Forestry Terminology*. Third Edition. Society of American Foresters, Washington, D.C. 1958. P. 34.

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That children of all ages be exposed not only to small parts of the whole but also to a philosophy which emphasizes the place of these parts in the total scheme are equally important. Careful observation must be followed by thought if we are to learn from or attempt an understanding of the forest or any other community in our environment. Certainly the foundation upon which to build is through the use of concepts, and children can be exposed to them in the forest as well as in the classroom. The basic idea of food chains takes on a new and fuller meaning when one examines the holes in a leaf only to look upward and see the fat eater or another of the same species firmly in the beak of a downy woodpecker.

Similarly, the idea of interrelationships is basic to observation in the forest. The small hooks on the burs of agrimony seem rather ignoble at first. Yet upon close examination, one discovers that these hooks are remarkably adept at clinging, especially to nappy surfaces. These seemingly delicate hooks, together with the unconscious help of forest mammals, become a very tenacious method of seed dispersal. The relative abundance of squirrels and other fur bearers in the oak-hickory forest may be a partial answer as to why there are more numerous plants with sticking seeds in the oak-hickory forest than in its maple counterpart. Here we have looked at more than the wrapping. Haven't we started to untie the package?

The school forest has "action" to observe and more than enough phenomena to try and comprehend; this resource of the forest we cannot ignore. Shakespeare stated it eloquently when he wrote:

> *Charmian:*
> Is this the Man? Is't you, sir, that knows things?
> *Soothsayer:*
> In Nature's infinite book of secrecy, a little I can read.
> —*Antony and Cleopatra*, Act I, Sc. 2

Attitude Formation. If learning is to become a joy (albeit there is drudgery, too) as it should be, the school forest can play a vital part. Unlocking the mysteries of a fallen tree, of jutting outcrops, animal remains, or newly formed cavities is fun as well as intellectually stimulating. There are countless aspects of the forest we fail to understand. May not the intellectual humility thus gained be transferable to attitudes toward our total environment?

Participants in the work-study academic credit program at work on the edger.

If one learns to care about a portion of his total environment, there is a strong possibility that this sense of husbandry may envelop the total. For example, few youngsters, or adults for that matter, will fail to be awed by the radiant plumage of the scarlet tanager as it leaves its high, secluded perch for a moment's rest on a sun-splashed shrub. Why can't the feeling that here is a thing of beauty, with its summer habitat preserved for future generations, be extended to the desire for a similar type of circumstance within the city. Why can't we rekindle the desire for a river whose rocky shores are washed by clear water rather than by a frothy film or the unnatural excesses of algal bloom? Can the feeling for a purposeful and ecologically sound harvesting of trees be transferred to the urban scene with the concomitant desire for housing which provides more than just physical living space?

Clearly, if the previous questions and the hypotheses they imply are to be more than idle dreaming, we must think creatively and design research which tests their credibility. Until then, we find ourselves in a comfortable, but untenable, position of believing that the hypotheses may be valid because we would like them to be.

Without doubt, a "land ethic," "ecological conscience," "environmental awareness," "a sense of husbandry," or any other words that connote understanding, reason, and responsibility toward our environment denote an attitude needed not only in those who have the power to make decisions affecting the environment, but in our youth as well.

Work. The opportunity for nonprofessionals to work in resource management is a valuable asset, yet we often overlook its significance. Just as there is no easy road for acquiring a sense of husbandry toward the environment, neither is there one best way. For many, the acquisition of a "land ethic," tragically, may never develop; for others, observation and intellectual activity fail to produce it. For example, when in the course of Madison's unique high school academic credit program water-current deflectors are constructed to help develop a clear bottom and deep pools in a silt-laden trout stream, a tree is seen as something more than beauty or habitat. It can, according to a sound plan, be marked, felled, sawed, and used to build a necessary facility. Work is required—and hard work at that. But so much the better, for lasting attitudes are often the result of attaining difficult goals.

Above all else, a resource management work program gives students and adults alike the opportunity not only to get involved but also to test their depth of commitment in developing or nurturing a "land ethic." Whether the work means a homemaker becoming a part-time naturalist, a logger overseeing felling operations, a teacher supervising the marking of a natural area, a garden club funding and taking part in parochial school tours, or support of another nature, is immaterial. What is important is the common recognition that experience of this type can be basic to awareness and a sound philosophy of land use.

Living Together. Last, but by no means least, the Madison School Forest provides a place for all to live, play, and learn together. Perhaps today, with our often super-fast life, the crowded cities with their inherent tensions, and the widening gap between material affluence and poverty, we need this experience more than ever. A setting which places all in similar living surroundings with a successful experience resting on near total participation is, of itself, useful and rewarding. Further, to let children experience this at an early age is even more beneficial.

The author, along with others, recently witnessed important behavior changes within an assemblage of elementary school students, which may be attributed to living together in the school forest environment. For six of the eight weeks included in the classroom program a group of Indian, Negro, and white fifth- and sixth-grade children representing culturally diverse backgrounds exhibited more than the usual anxieties, conflicts, and lack of student rapport—perhaps reflecting the social disorder and problems facing older generations today. However, after a three-day living, playing, and learning experience in the Madison Forest, a noticeable change occurred. The program jelled, rapport was better, and productive activity was measurably increased. Obviously, without a carefully designed experiment, a causal relationship can not be inferred. Yet, there is a strong possibility that the forest camping program was instrumental, particularly since these children had been living together in a dormitory prior to the school forest experience. Further, a similar situation had followed the same experience during the 1967 summer program.

Students from the University of Wisconsin Summer Laboratory School discuss collections with Mrs. B. Kline, coordinator of naturalists and education for the forest.

WHAT about opportunities in other forests, a prairie, or another biological community? Cannot many, if not all, of the above-mentioned aims be accomplished in other areas as well? Yes and no. Yes, it is possible to observe and learn; think critically about natural phenomena; develop a sound "land ethic"; work; study and live together in almost any forest or other natural community. Indeed, many school forests have differing communities in conjunction with or within their boundaries. However, it is not only the natural or physical qualities of the forest that matter; more importantly, it is a "school" forest. If it is true that exposure must precede interest, then tell me who will take Johnny, the small raggedly dressed lad with bright eyes and quick mind and introduce him to the hitherto (to him) unknown forest drama? Johnny is in the fifth grade, and it's his first serious encounter with any community other than the city and its ghetto. Who will help Mary, who has returned from a camp experience brimming with enthusiasm and the need to explore further her interest in natural science and the environment? Her parents pursue professional and social careers which offer little time for helpful assistance. Or Larry, a country boy whose practical knowledge and keen insight concerning ecology need guidance as he explores scientific observation? A school forest can help all three.

A forest belonging to any type of school system—elementary, secondary, or higher—if properly viewed and used is more than a forest. Above all, it may enlighten the student through new knowledge, which may be transferred into creative thinking, generating a new interest in the world about him. This is particularly likely if (and they must be) political, economic, and social considerations are combined with natural history and ecological concepts. Further, it presents unlimited opportunities for teacher and student alike to participate in that all-important aspect of education—"learning to learn." Finally, the school forest is a positive force in developing or nurturing a much-needed "land ethic" among our youth. To do this requires participation by all who share a concern for our environment, whoever they are or whatever their calling. Doing this and more may let us live and think, not apart, but one with our surroundings. To do less will be unfortunate. □

Ecology—

A Practical Program in a Suburban School

N. FRANKLIN BURNETT

Science Teacher
Creston Junior High School
Indianapolis, Indiana

AUTUMN visitors to southern Indiana's Brown County State Park were startled last year when 35 boys and girls, wearing green-and-white armbands, descended on Jimmy Strahl Lake. Carrying plastic litter bags, they had come not to view the fall coloration, famous throughout the state, but rather to clean up the summer accumulation of debris. Within three hours several barrels of trash had been collected, and the group was gone. Who were they and from where had they come? To answer this question, we must go to a junior high school in the central part of the state.

Approaching the city of Indianapolis from the east, one crosses the Marion-Hancock county line and travels past the well-kept farms and homes of suburban Warren Township. Warren, along with most metropolitan areas, has changed in recent years: New industries are building on sites in its western portion. Agriculture, still predominates along the eastern boundary, but vies with housing developments that take up more and more space. The people, like concerned citizens everywhere, are anxious about pollution and view the phenomenon of modern progress with mixed emotions. What sort of impact is this environment-jarring growth having on the quality of their air and water? No one really seems to know.

As a result of the community concern, some seventy students at Warren's Creston Junior High School decided to learn what they could about the real situation. Organizing a movement which they call Mission: ECOLOGY!, they are carrying on a systematic study of their environment.

One of the first steps of any organization is to determine its objectives. Since ecology may be broadly defined as the study of the relationship of all living things to their environment, it was decided to investigate not only the effects of man upon his surroundings but also the interactions between the environment and the life forms within it. On the basis of its findings the group would then attempt to improve the area. In addition, Mission: ECOLOGY! would try to stop pollution before it started, would inform the public about the importance of ecology, and would work with other community groups on ecological problems. Parent-teacher organizations, church groups, and civic officials are all concerned with this vital subject.

A topographical map showing stream beds, elevations, railroad rights-of-way, and other natural and man-made features was displayed in the hallway of the school. The map indicates the effects of the great ice sheet that in recent geological history swept down from the north to flatten the central portion of Indiana. In Warren Township only the paths of such flowing streams as Buck Creek, Grassy Creek, and Pleasant Run—their meanders marked by lines of trees and scattered patches of woods—relieve the monotony of the terrain.

The map was divided into grid squares, and the home of each student marked with a colored pin. This made it possible to select committees to investigate ecological problems within a specific location. The first overall

WILLIAM OATES, INDIANAPOLIS STAR

The members of Mission: ECOLOGY! try not only to study and improve their local area, but also to inform the public about the importance of ecology and to work with other community groups on local environmental problems.

view of their school district was exciting to many of the boys and girls, especially when they found their own homes marked on the map.

MOST young people are fascinated by a pond, lake, stream, or any type of aquatic environment because, like a new frontier, its secrets are not so easily discovered. One part of the group quickly became interested in preserving the quality of the surface water and began its study by establishing water-quality measurement stations within the township. Selecting a body of water, such as a pond or gravel pit, they plotted three points of reference on its surface by using surrounding landscape features. In teams of two, and under adult supervision, they then rowed to each position to begin collecting data.

The students made their own Secchi disk, depth recorder, and water sampler. The Secchi disk, a black-and-white circular metal disk 20 centimeters in diameter, is used to measure water turbidity, or the depth to which light penetrates.[1] Collected samples of water were returned to shore where other students, using a commercial testing kit,[2] determined the degree of free acidity, the pH factor, the dissolved oxygen, and the mineral content. Back at the laboratory, other samples were used to inoculate bacterial culture plates for coliform bacteria.

Mission ECOLOGY! uses the membrane filtration method[3] for testing water to detect coliform bacteria. When a sample passes through the filter, microorganisms larger than filter pore size remain behind on the filter surface. They are then cultured and, in the procedure, develop a green metallic sheen which makes it possible to obtain a direct colony count in 24 hours. The coliform group of bacteria, while not pathogenic in themselves, usually originate in the intestinal tracts of warm-blooded animals including man. They serve as a reliable index of contamination since they indicate the possible presence of other enteric organisms, such as those causing cholera, dysentery, and typhoid fever. The Marion County Indiana Health and Hospital Corporation has agreed to check duplicate water samples if any high bacterial counts are noticed.

Evidence collected so far indicates that the quality of the standing bodies of Warren Township surface water satisfies the standards established by the State of Indiana. The mineral content is high, especially in the gravel pits, and in some cases the pH shows the water to be somewhat alkaline.

Altogether, five different locations were tested during the last school year, but the students hope ultimately all bodies of water 90 centimeters or more in depth and all major streams in the township will be continuously monitored for pollution factors. They also plan to run nitrate and phosphate tests because of the agricultural activities carried out in the area.

ANOTHER group, wishing to determine the degree of air pollution, prepared 45 air-sampling kits. Each of these kits was a one-pound coffee can painted with a rust preventive undercoat and a green outer coat to which an explanatory label was attached. Inside the can, a numbered Vaseline-coated slide rested on clean gravel. Each slide was exposed in one of the topographical grid locations for 14 days. A few kits were also placed in downtown Indianapolis so that the pollution levels of the two areas could be compared. Thirty-eight of these cans were recovered in good condition, and the particulate sedimentation on the slides was studied. Observations indicated that slides exposed in the inner city were in fact more heavily contaminated, those at busy intersections being especially so.

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[1] For directions for making such a disk, see "The Secchi Disk: An Instrument for Measuring Water Transparency," by Thomas P. Evans, in the April 1971 issue of *The Science Teacher*. (See p. 190.)

[2] The Hach Chemical Company of Ames, Iowa, manufactures a number of self-contained water-testing kits for field work, one of which was used by these students.

[3] The Millipore Corporation of Bedford, Massachusetts, will forward reference materials. See also "Membrane Microfiltration for the Science Lab," by Bernard I. Sohn, in the November 1969 issue of *The Science Teacher*.

After being examined under the microscope, each slide was bioscopically enlarged and exposed on photographic print paper so that a permanent record could be kept. We plan to set out kits in the same locations next year.

The group is especially interested in hydrocarbon particles. These appear under the microscope as black flakes with fairly smooth-textured bumps on the sides and have a crystalline appearance. The major source of this kind of pollution is the burning of gasoline in automobiles. The particles are discharged into the air by incomplete combustion. Included in the more than one thousand known hydrocarbon compounds are several known to be cancer producing.

THE students have begun the cleanup of several illegal dumping areas in the township and will keep continuous watch on these. Locations where railroads and stream beds are crossed by public roads are especially vulnerable to misuse. Raw garbage and other material constitutes a definite health hazard, and it is estimated that the group has been responsible, directly or indirectly, for the removal of four tons of trash from these areas in a three-month period. Plans are also being made to survey all creek beds; sections of Buck Creek have already been cleaned. In addition to picking up litter, the students hope to obtain the consent of property owners to remove fallen trees and other debris blocking stream flow.

STOP POLLUTING
WHAT DO YOU WANT
THIS OR THIS

RODGER BIRCHFIELD, INDIANAPOLIS NEWS

A student sign asks polluters to make a choice. The sign shows two scenes, one of a green field with healthy trees and a blue sky and the other of a barren field, leafless trees, and a polluted atmosphere.

A committee of eight students presented a special program to various classes during the school's daily activity period. The program consisted of an ecology play designed to illustrate the importance of our natural environment and the possible effects of the destruction of our natural resources. A second group invited interested nonmembers to ecology film presentations.

Any student is encouraged to submit reports of existing ecological problems to Mission: ECOLOGY! The problem is read and discussed during the meeting, and appropriate action is suggested. The group then decides whether or not to accept it for action. Problems submitted to date have included traffic guard rails in need of repair and painting, polluted streams, illegal dumping areas, streets with large chuckholes, ponds with chemical imbalance, and sewage backups.

MISSION: ECOLOGY! also tries to maintain contact with others who are concerned about our environment. Its correspondence includes brief "thank-you" notes to authors of letters to city newspapers and lengthy analysis of pending ecology legislation, this latter being mailed to state senators and representatives. Of major concern last winter was the Indiana Environmental Act being discussed by the legislature. A delegation of students attended hearings on this Act at the state capital.

Another matter in which the students have taken an active interest is the "Big Walnut" controversy. Big Walnut Valley, located 35 miles west of Indianapolis, is the site of a proposed water storage reservoir. It is also the location of an entire ecological life system qualifying as a National Nature Landmark. Among the natural features which would be affected by such a reservoir are the largest hemlock trees in the state, a stand of Canadian yew trees which are quite rare this far south, and one of the largest blue heron rookeries in the nation. Thirty members of the group visited the location, and then each mailed at least one letter to one member of the five-man committee established by Congress to restudy the proposed reservoir site. Such activities as these contribute a great deal to the growth of responsible citizenship.

And this, of course, is what it is all about. Warren Township, by itself, is just a dot on the map of the United States, a microcosm on the spaceship Earth. If the environmental conscience of these boys and girls can be awakened, if others can view such a happening, and if the idea catches on, young people like these can turn the nation around—can move toward a cleaner, better world.

But, nevertheless, if someone, somewhere, does not react, does not fan the spark into a flame, then, as the chapter of Genesis rewritten by the students at the University of Wisconsin tells us, "on the seventh day man will rest from his labors and the earth be still. For man will no longer dwell upon the earth. And this is good!" □

Interdisciplinary Involvement

in Environmental Field Trips

RON OSBORN and ROGER SPOFFORD
Science Department Chairman and Science Teacher, respectively
Jamesville-DeWitt Middle School
Jamesville, New York

ENVIRONMENTAL studies increasingly have as their objective the creation of a concern for all environments. This leads to a commitment to preserve optimum environments and improve less desirable environments. Further, environmental studies develop situations and conditions where learning can flourish. By utilizing a nature center or other outdoor study area wherein an intense learning experience can be enjoyed by the students, opportunities for relationship to other parts of the curriculum can be developed. For this purpose we use the Fellows Hill Center.

Fellows Hill is a New York State reforestation area near Fabius. It has been set aside and managed by the New York State Conservation Department, in part, as a "wildlife refuge," for game birds, deer, and other animals. Seventh-grade classes of the Jamesville-DeWitt Middle School use the area as an outdoor laboratory to study the ecology of a pond environment, to observe animals in a natural setting, and, we hope, to awaken a sincere interest in the outdoor world. Though the full-day field trips are aimed primarily toward science, certain activities are arranged to include mathematics, reading, social studies, and English.

Science Activities

The science activities include collection of some specimens that can be taken back to the classroom for study and on-site study of larger plants and animals that cannot be removed from the observation area. The students are divided into nine groups with the following assignments:

A — Study of microscopic organisms
B — Study of bottom-dwelling organisms
C — Study of larger plants
D — Study of larger animals
E — Collection of pond-water temperature data at various depths
F — Mapping the surface area and features of the pond
G — Measuring depth of pond along several different transects
H — Estimating heights of various plants and trees surrounding the pond
I — Estimating populations of various pond plants and animals

Below are field-trip instructions for several of the study activities undertaken by the youngsters in the Howland Island area of the Fellows Hill Center:

GROUP A: *Collection of microscopic organisms*

Materials:
Coffee cans and covers (labeled as follows):
"Surface-water Zone"
"Deep-water Zone"
Plankton net
Test tubes and plugs
Twine

At the pond, fill the cans about one-third full of pond water. Using the plankton net, collect samples of pond water, first at the surface, then in the deeper water. To use the plankton net, attach a test tube to the net by pushing it through the hole in the bottom (from the inside). Cast the net into the water and pull back and forth. If the net is pulled rapidly, it will stay near the top of the water. Then untie the test tube from the net and empty into the can labeled "Surface-water Zone." Collect three or four samples from near the surface. Then collect samples from the deep-water zone by allowing the net to sink to the bottom first, then pulling along slowly and evenly. Place three or four samples from the deep-water zone in the can labeled "Deep-water Zone." Leave the cans in the shade until you are ready to leave.

Group B: *Collection of bottom-dwelling organisms*

Materials:

- Three coffee cans (labeled as follows):
  - "Emergent-plant Zone"
  - "Submerged-plant Zone"
  - "Open-water Zone"
- Three gallon jars (labeled as above)
- Sieves (with wooden frame)
- Unlabeled coffee can (for scooping up mud)
- Twine

At the pond, fill each of the jars and cans about one-third full of clear pond water. With the cans, scoop up mud from the bottom from among the emergent plants (the ones coming up out of the pond above water level, near the shore). Dump this mud into the sieve; then shake the sieve in the water (at water level) until the mud is washed out. Remove dead sticks and leaves by hand. Pick out whatever organisms you find and put these into the larger jar labeled "Emergent-plant Zone." Repeat this procedure for the other two zones (progressively farther away from shore), placing the animals you find in the correctly labeled jar. Finally, scoop up a sample of mud from each zone and empty into the labeled coffee cans.

Group C: *Collection of plants*

Materials:

- Three large plastic bags (labeled as follows with 3- x 5-inch cards dropped into each):
  - "Emergent Plants"
  - "Submerged Plants"
  - "Floating Plants"
- "Twist-ems"—(wire ties for bags)
- Hand trowels
- Plant-grappling hooks
- Twine

In each of the three plant zones, collect a sample of each kind of plant found. The "emergent plants" will be found closest to shore, the "submerged plants" out beyond the shore zone below water level, and the "floating plants" out in the open water. The plant-grapplers can be used to collect the plants in the last two zones. Whenever possible, try to get the whole plant. If the plant is too large, take the leaves and flowers only. Put the plants of each zone into the correctly labeled bag.

Group D: *Study or collection of certain animals*

Materials:

- Four large pails (labeled as follows):
  - "Emergent-plant Zone"
  - "Submerged-plant Zone"
- Ten small jars (labeled as follows):
  - "Emergent-and-floating-plant Zone"
  - "Submerged-plant Zone"
- Dip nets

Two members of the group should record on paper the animals seen but not collected. This should include all animals that seem to be a part of the pond community, whether they live *in* the pond or not.

Use the dip net to collect some of the larger animals—for example, fish, crayfish, larger insect larvae, turtles, etc. First catch the animals in the shore zone near the edge of the pond. Insect larvae may be placed together in the same jar, with some sticks and leaves for shelter. Only a few fish should be placed in one jar. Be careful in handling animals: some may inflict painful bites. On return to the school, place the animals in a cool place, *not* in the open sun.

Choose one animal you find in or around the pond to observe and write a short essay describing, in detail, the behavior of the animal for the period of time you observed it. It would be easiest to choose some water insect you find. Draw or sketch one of the plants or animals you have seen on the Howland Island Game Preserve. If you do not have time, this can be done back in class. Make a map of one of the two ponds—show outline of shoreline of pond, put in the location of the inlet and outlet streams, locate on the map shallow areas of pond and the probable location of deepest point. Mark your positions (locations), during both the morning and the afternoon session, on the map found in this field guide.

Mathematics

The youngsters gather data for later use in class of the estimated numbers of certain plants and animals. They also measure the pond depths at various points as shown in the diagram and map the bottom of the pond.

English

The English assignment includes making notes for use later in composing a short poem of the Japanese *haiku* type. These poems are usually about the world of nature and include the word for one of the seasons. Each haiku has three lines with five syllables in the first, seven in the second, and five in the third.

Another assignment for the English class is an imaginative composition, telling how one of the living things around the pond might perceive the world in which he lives.

Social Studies

In the social studies assignment, the students are asked to imagine themselves as a member of a pioneer family, as follows:

The Blake family has just moved from Sturbridge, Massachusetts, to Fellows Hill, New York. The year is 1803. The travel was mainly by horse and wagon, and the entire trip took three long weeks. Upon reaching their destination each member of the Blake family had a very different outlook or "umwelt" regarding their new home site.

Write a composition choosing *one* of the four possibilities.

1. You are Sarah Blake, the mother of the family. How would you see Fellows Hill? What space patterns would you miss and what space patterns would you hope to create?
2. You are Noah Blake, the father. How would your "umwelt" affect your opinion of trees. What steps would you take to make this an acceptable homestead for your family?
3. You are Eliza Blake, an eleven-year-old daughter. You did not wish to leave Sturbridge, Massachusetts. You had many possessions you wished to bring with you and could not. Your mother told you that you could have one-eighth of the trunk. (Remember the trunk at Erie Canal Museum.) What did you bring with you and why?
4. You are Johnny Blake. You are the thirteen-year-old son. You were very anxious to leave Sturbridge, Massachusetts, since you felt it had been too crowded in the last few years. You were afraid that there would be no "open land" for you to start your own homestead. How would you see Fellows Hill and why? What area would you hope to make as your own homestead in the next few years? Do you think you would prefer to "stay on" with Pa? Why?

Reading

One reading exercise is based on a magazine article on migrating birds, with questions covering both comprehension and vocabulary. Another includes a set of "Did You Know" queries about some of the unusual characteristics or name origins of plants and animals found near a pond in temperate zones. Following are a few of the queries. Students themselves might make up such a list for any environment to be studied.

—that the *liverwort,* a water plant, is simply a liver-shaped plant? "Wort" was the old English word for root or plant, and in ancient times people believed the liverwort would cure diseases of the liver.

—that the *plumatella* is also known as a "moss animal"? Can you guess why?

—that the life story of most water insects and the change which transforms them into winged creatures is called *metamorphosis,* an ancient Greek word that means "change of form"?

—that birds in open nests generally lay spotted eggs while dwellers in tree trunks, burrows, or buildings tend to produce white ones? Why? □

Unearthing an Indian Culture –

A Total Involvement Program

DUANE GETTINGS

Coordinator of Science Activities
Raymer Junior High School
Toledo, Ohio

FOR many years the study of American Indian cultures has been traditionally pocketed in the social sciences curriculum. There is little question that this placement is proper and justified, but this study should not be exclusive to social studies. Indian culture can also be a fertile field for science education.

During the last two years, the more than two hundred science students at Raymer Junior High School in Toledo have been doing field work on an extinct Indian culture. In the heart of Toledo's industrial east side, bordering the heavily traveled Detroit-Toledo expressway, young science students are cautiously unearthing the remains of a once-active Indian settlement. On this scrub-covered piece of land, slated to become an expressway exit ramp, the science of the classroom is receiving the test of the field.

The investigation is part of a new "Total Involvement Program" (TIP) instituted at Raymer to stem a growing tide of disinterest by urban students in the conventional textbook-oriented courses. Scholastic apathy was apparent and growing, with burgeoning lethargy and downright resentment. To alleviate present and anticipated problems, TIP was scheduled during afternoon classes, two days each week.

TIP is a program of curriculum integration and outdoor experiences; it engages all school departments. Students receive instruction in pottery making in their art course and then manufacture their own vessels, employing the ancient coil method. Language arts teachers present techniques of careful record keeping, which are then employed in the compilation of vital field log reports. Surveying, outlay techniques, and field mapping are the responsibility of the mathematics department. Tripods, sifting screens, and stakes were manufactured in industrial arts classes. This department has the added duty of keeping shovels sharpened. The social studies department thoroughly covers the culture of the early Indians.

Several hundred junior high school students are now conducting an archaeological investigation of an Indian dwelling first mentioned by the French explorer, Peter Navarre. The site, located along the Maumee River in Ohio, was leased from the City of Toledo. In the future it will become an artery of the Detroit-Toledo Expressway.

Students work on a sumac covered knoll, which has remained unmolested since the Indians left. At each of ten pits, teams of eight students scrape the soil from the floor of the pit, one inch at a time. Other job assignments include testing soils, identifying and preserving plant specimens, and photographing and cataloging their discoveries.

An archaeological investigation was unanimously favored by the teaching staff. They assumed initially, however, that sites were available only in America's Southwest. This assumption proved to be erroneous. A member of the teaching staff at Raymer, Kenneth Brown, also happened to be a local history buff. While reading the diary of Peter Navarre, an early explorer and trapper in northwestern Ohio, Mr. Brown first found mention of the location of the site. A few elderly residents in the area recalled their parents' comments on the existence of an Indian settlement at this location. Before any investigation could proceed, ownership of the property had to be determined. The tract proved to be city property, and the site was leased to the school for a five-year period.

The next step was a concerted effort on the part of all teachers at Raymer to develop a curriculum centered around an archaeological investigation. In this effort, the science and social sciences departments joined forces to produce a 30-page booklet on the techniques of scientific archaeological investigation. Students were then given an intensive three-week course, employing the booklet as their text. Written on the junior high level, the guide outlines the duties and procedures for various project assignments. After several general orientation periods, students make their choices of work assignments from the following:

A Study of Rocks as Indications of Human Habitation
Chemical Analysis of Soil Samples and pH Testing
Study of Seeds and Other Plant Materials Found in Subsoil
Weed and Plant Samples and Identification
Site Mapping (Local Maps)
Art Work
Survey Crews
Excavation Crews (Full Time)
Test Pit Crews
Field Sorters
Identification and Cataloguing of Animal Remains
Identification and Cataloguing of Human Bones
Log Recorders
Photography of an Archaeological Investigation
Equipment Men

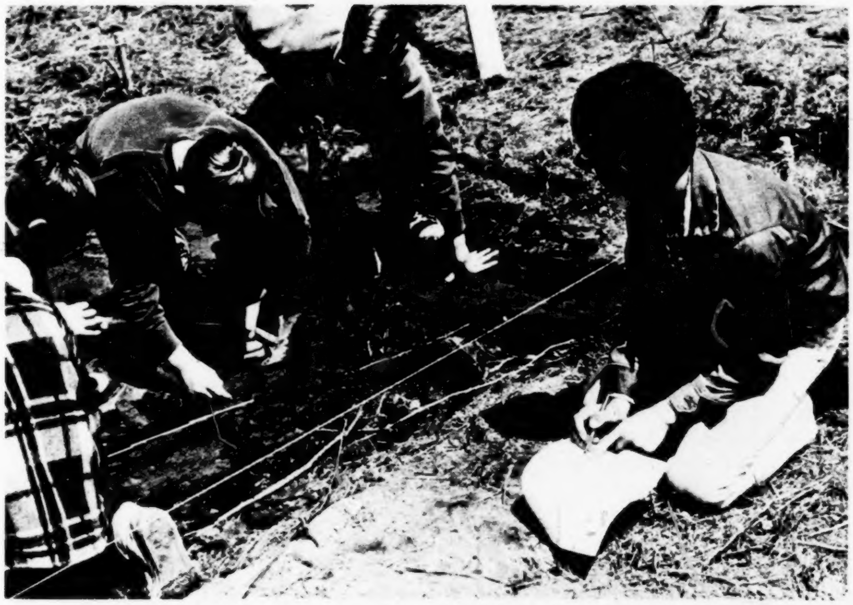
Each student is given specific instructions and is tested in a laboratory situation before being permitted to engage in field work. A simple statement of project choice does not "lock" a student into that assignment. Many have dual duties. Some students have specified a desire to catalog human bones, but, as yet, human bone has not been unearthed. These students have been assigned to their second choices. No student is without a responsibility, and many of the less academically minded have become conscientious equipment men, survey and test-pit crew members, and field sorters.

Many of the facilities and services available within the community have been employed, and interest on a community-wide scale is much in evidence. Equipment is stored in a nearby hothouse complex, shovels were purchased below wholesale prices from a local garden center, and each crew of youngsters is supervised by an interested adult, leaving teachers free to move between the various pits. Each group consists of eight field crews; each crew, in turn, is made up of eight student members.

Of paramount concern to the science department are: chemical analysis of soil samples and pH testing, the study of seed and other plant materials found in the subsoil, identification and cataloguing of both animal and human bone, and photography of the archaeological investigation.

Deep community commitment is exemplified in the photography project. The Photographic Club of the East Toledo Boy's Club, a neighborhood group, equips project photographers with 35 mm cameras and trains students in darkroom procedure, composition, and the mechanics of photography. It then permits the students the use of club facilities to develop, print, and carry on their photographic assignments.

Students in this project have produced work of such high quality that several project photographs were entered in a national contest sponsored by the Boy's Clubs of America and one was selected a winner!



Each team includes a log recorder who draws each discovery in on his pit map.

Each flint tool or weapon is photographed. Included are a measuring stick and an arrow pointing north.

The sifting crew shakes each inch of soil removed from the pits through fine screens.

NOT all assignments can be completed in the field. Some require laboratory facilities and can be concluded only after exhaustive work in the classroom. When weather conditions preclude field work, students remain in school and are found diligently testing their soil samples, cleaning the potsherds and animal bones, numbering and cataloguing specimens, and reconstructing flint fragments into aged, but formidable, weapons.

In the field, each potsherd, flint chip, bone fragment, or fire-cracked rock is entered on a field log sheet. Specimens are placed in numbered containers and carefully stored for future cleaning, identification, and reconstruction where possible.

At the end of the day, the field log sheets for each pit are entered in the master catalog, which contains a detailed photographic, written, and sketched record for each inch lowering of the pit floor. Thus a complete record of progress of the project is maintained and available at any time.

Financing the project—an ever-present problem—was solved by a concerted school campaign. Contributions were received from the school newspaper and from the science club. Students in the industrial arts department mass-produced letter holders, which were sold throughout the community. The shovels were purchased with funds made available by the Toledo Board of Education. It has been estimated that, to date, the entire project has been financed at a cost of just under $100.

From its inception, the Raymer School Archaeological Investigation was intended, primarily, to provide a meaningful and unifying activity for all students, regardless of their ability. This investigation is intended to continue for the next four years, and if the first year's response was any indication of its success, the total involvement approach in science education on the junior high level has been firmly established. □

Science, Nature—

and the Survival of Man

IRVIN T. EDGAR

Science Education Adviser
Bureau of General and Academic Education
Pennsylvania Department of Education
Harrisburg, Pennsylvania

WHAT
HAPPENEd
Those Mon
AND CReeP
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SCIENCE educators, as well as educators generally, appear to search for new ideas or "fads" after which to model programs of instruction—or so it would seem to the casual onlooker examining science programs.

In reality this practice of identifying existing issues and altering instruction to address those issues is not simply faddish behavior. In most cases it is an honest attempt to remain viable in a changing world of student and citizen needs. There is, in fact, little blame to be associated with the process of maintaining a current focus in science education. The real tragedy is that usually we are guilty of identifying issues, altering our instruction, and creating materials for a restricted segment of our student population—the science major and college bound. With few notable exceptions, the lower ability and nonscience major student groups have been viewed as problem areas of the science curriculum, insensitive to change. Such groups have been staffed with the inexperienced or ineffective teacher who owes his assignment to noneducational considerations, such as approaching retirement, ability to discipline students, an opening in the teaching schedule, and so on. And yet teacher assignment is not the sum of the problem; another is the curriculum provided for these students.

Statistics indicate that working scientists comprise a small proportion of society. Members of this specific group and students preparing for this career do have definite needs which are often vastly different from the needs of the nonscience major student. Nevertheless, the familiar practices of simplifying science curricula and lowering the science dosage still persist and are thought sufficient for nonscience majors.

We seem to expect that these students will be able to assimilate the specific scientific information we provide to them and reorganize it into an integrated whole which they can use in reacting to the larger questions faced by citizens. Naturally, this does not occur. Instead these students form societies with other adults from similar student groups and share both their lack of information and dislike of science. In general, student instruction for nonscience majors is often characterized as lacking appropriateness and as being concerned with ideas which do not relate to subsequent adult needs, prepared without benefit of a rationale concerning student abilities and wants, and administered without benefit of enthusiasm. Clearly, change in this area of the science curriculum requires a broad frontal attack on the problems.

OUR program, "Science, Nature and the Survival of Man," [SNSM] was created by a committee of individuals to address the needs of nonscience majors through the design of an appropriate curriculum and the establishment of a mechanism to overcome the constraints described. The currriculum grew out of the following considerations:

1. The study of science should revolve around the immediate issues and problems of society.
2. Students should be helped to recognize their future roles as citizens who will influence science and society.
3. Students should be active in the study of science, and the starting point for student study should be identification of science-related problems that are part of the student's environment or community.
4. Students should learn to be flexible in their thinking and to base their conclusions on currently available evidence. (Dialogue with the teacher was recognized as imperative here.)
5. Students need to view science with greater objectivity and without the biases and unfavorable attitudes toward science characteristic of much of the past science study. [3]

These considerations, outlined in 1968, resulted in the present SNSM program. It appears to be satisfying a majority of its goals for student behavioral and attitudinal changes.

Initially, the committee did not intend to produce an environmental curriculum. In fact, the SNSM committee's efforts predated this general concern. The emphasis on student study of immediate social issues eventually directed the development of the program; and because student study of science-related problems in their own community was encouraged, the respective school programs in SNSM assumed a varied appearance. Since student attitudes toward major issues represented a focal point, an SNSM Scale was developed and used with both teachers and students. It emphasized student attitudes toward family size, costs of pollution, discarding of wastes, noise control, radioactive substances, product design, citizen responsibility, and other problems.

To mobilize the efforts of school personnel to develop and test the SNSM program, an experimental program was mounted. This provided the necessary official sanction and created the conditions where a concept and materials could be tested rather than the skills of participating teachers. The results were sufficiently encouraging, and the second year or pilot program is now in effect.

The experimental program, begun in eight schools with approximately 400 students, started slowly with most individuals unsure of their teaching responsibilities. Eventually, students began to respond to the instruction, and communication between students and teachers started. The activities conceived by the students turned out to be more far-reaching than those suggested by the committee.

GENERALLY, the issues students identified fell into two categories —population and pollution. One of the most dramatic activities regarding pollution involved a student collection of discarded materials in one community. When the litter from a few blocks is placed in a pile, the results are impressive, and the message concerning an individual's contribution to litter control in his own community is inescapable.

One student constructed a questionnaire for use in a neighboring community where the polluting effects of a local industry were all too evident. When questioned, the community's residents indicated their awareness of the problem and their recognition of the deleterious effects of this pollution on their community, but not a single citizen considered that he might be able to do something to correct the problem.

In another instance the effects of pesticides on seed germination were investigated, and the student concluded that seed exposure to pesticides retarded germination.

Population study is not a unique activity in science. However, the need to learn how a population is defined and its members determined by techniques of classifying is generally presented in an abstract way. In SNSM, the students learned about populations and classifying by examining cars in the school parking lot. The variations and characteristics the students recognized in the cars were surprising. The effect of time on studies of this sort was obvious, and students recognized that their results would have been vastly different on a Saturday or nonschool day. Naturally, population studies and the limiting factors of population need to be generalized to humans. The experimental program did not succeed entirely in drawing this relationship, and student responses indicated a need for further emphasis on this point in the present pilot program.

Air pollution study stimulated one student to construct an electrostatic precipitator for the removal of particulate matter from smoke. In addition, Earth Day posters showed considerable preoccupation with the visible ingredi-

PENN MANOR HIGH S
THIS
JUNK
WAS COLLECTED
FROM:
• 300 YARDS ALONG
THE CONESTOGA CREEK
• KREADY ROAD
• ONE MILE OF THE
MILLERSVILLE ROAD
• FREDERICK STREET
IN MILLERSVILLE

Nonscience major students show strong interest in issues related to population and pollution. One project involved collecting discarded objects in a community.

ents of air pollution. The invisible and gaseous components of air pollution are receiving greater attention in the pilot program.

One unit of study provided a source of controversy, and questions were legitimately raised about experimental study of "hard" drugs in the secondary school. Nevertheless, a unit on drugs enabled many students to investigate the effects of smoke inhalation and alcohol consumption on mice. The visible effects were considered sufficient to establish cause and effect.

The controversial nature of drug study grew out of the students' producing a variety of "hard" drugs which they wanted to study. Without the necessary legal sanction and careful procedures to obtain such drugs through acceptable sources, such study is hazardous and ill-advised at best. Nevertheless, one lesson was painfully clear to the SNSM experimental teachers—drugs are commonly available to many high school students even in the most attractive and wealthy communities; and drugs can be a center of focus for students.

Additional activities in SNSM included devising innovative transportation systems, including projected costs; making population studies of forests and other natural areas; visiting community agencies faced with many of the problems under discussion; examining radioactive materials; and studying life's requirements in space travel, with constant comparison to the earth and its finite resources. These and many other activities have been compiled and placed in a printed SNSM Guide.

WHAT did the experimental program reveal? Nonscience majors can learn to discuss current issues intelligently with teachers and can even provide guidance to the teacher about the issues. While there were weak spots in the overall program, there was considerable student change in the direction of the teacher's opinion regarding issues and ideas—so long as the teacher demonstrated a commitment to the idea and a respect for students' opinions. In addition, it was revealed that students recognize some of the problems that face society, though not all or even a majority of such problems. There is work to be done in this area, but there is also need to convince students that individuals can alter society through collective action and in this way cope with many existing problems.

As a result of research conducted during the experimental phase [4], the following points were identified as requiring more attention in the pilot program:

1. Radioactive substances can and are being used for peaceful purposes. Radioactivity is not always an instrument of harm.
2. A certain amount of pollution is an inevitable outgrowth of a technological society, so that the question is largely one of the amount of pollution man will be willing to tolerate.
3. An individual can take part in and influence the outcome of problems related to pollution.

SNSM certainly cannot claim uniqueness because of the involvement of students. Interesting parallels for student consideration of community problems exist in the Project Curricula of 1924. [2] It is hard to dispute the point that students relate to real problems best when they are allowed to see the problems firsthand rather than through oral or printed descriptions of such problems. The SNSM program subscribes to the philosophy expressed by Edward Ames as he explains the need for educators to understand and change the basic aspects of the school environment for environmental education:

> Furthermore, education will have to be organized around the goal of teaching children how to be effective agents for change so that they in turn may participate in the social processes which shape their communities and their lives . . . A high priority would be placed on the processes of inquiry and problem solving but the focus would be outward into the community and on actual problems affecting the lives of the students. [1]

The SNSM program offers this kind of an opportunity for the major, yet generally neglected, segment of the secondary student population. Instructional change to this type of an approach is not easy. Nevertheless the alternatives to this change are less and less acceptable for the education of nonscience major students. □

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Roll on, thou deep and dark blue Ocean—roll!
Ten thousand fleets sweep over thee in vain,
Man walks the earth with ruin—his control
Stops with the shore; upon the watery plain
The wrecks are all thy deed, nor doth remain
A shadow of man's ravage, save his own,
When, for a moment, like a drop of rain,
He sinks into thy depths with bubbling groan,
Without a grave, unknelled, uncoffined, and unknown.

From *Childe Harold's Pilgrimage,* Canto IV
By George Gordon, Lord Byron *

EDUCATIONAL STRATEGIES FOR AN ENVIRONMENTAL ETHIC

Ronald B. Linsky

PRESSING issues of water pollution and the increasing use of marine resources as actual and potential solutions to man's terrestrial problems indicate that the study of the marine habitats warrants a permanent place in the curricular offerings throughout our nation's educational enterprise. This is especially true in maritime states and, more precisely, in maritime counties.

Today we live in an age of "explosions"—atomic, population, and knowledge. The environmental, ecological explosion has now been added. Unfortunately, the hue and cry has now uncritically placed the environment alongside motherhood, apple pie, and the American flag.

Americans today are the greatest scapegoat artists in the world. You and I never do anything wrong. It's the guy next door or down the street who's the polluter. Until man can accept the basic, gut-level responsibility that pollution starts with himself, we will never develop an environmental ethic, which is basic to solving the many problems we are faced with today. The nonthinking human is doubtless the world's most prolific polluter. As he walks down the street, he harangues the belching, atmosphere-polluting automobile—but he never winces about the candy wrapper he's just let drop from his hand (turned incidentally with palm backward to make him feel less conspicuous to his peers) or the fact that any given summer Sunday he, along with 50 million American swimmers,

** Mentor Book of Major British Poets, New American Library, New York.*

The author is coordinator, Marine Sciences, and director, The Floating Laboratory Program, Orange County Department of Education, Santa Ana, California.

urinates freely into the ocean. Yet, he complains about not having adequate sewage treatment plants. He continually complains regarding increased taxes, but thinks nothing about littering his local beaches with cans and other rubble, causing an estimated 14 million dollars a month expenditure throughout the maritime states during the summer months to clean up after him and others like him.

An environmental ethic cannot be classified as good or bad, black or white, nor should it be confused with our culturally disjointed moral issues. Our very survival depends on the inculcation of an attitudinal ethic that will provide a positive pivot point for survival.

With today's rhetorical hub-bub and the squawking "eco-hot-jaw" poignantly pounding on young people about the impending demise of our worldly environments, there seems scarcely any evidence of what man can, in his infinite ability to compromise and to solve problems, do to alleviate many basic situations. The word "compromise" should be emphasized here since in the continual battles between the developers, conservationists, and preservationists, there seems little if any desire to invoke this solution pattern. Man must also recognize that prior to offering solutions he must first ask basic questions: What is pollution? . . . What are the parameters of the environment in question? . . . Are there identifiable cause-and-effect relationships? . . . What were the environmental characteristics prior to our contemporary problems?

Man must also recognize that pollution starts with *man,* and not with an oil company, his state capitol, or Washington, D.C. Pollution control begins and ends with man, the individual!

AMERICAN education today provides the optimum opportunity to develop programs aimed at inculcating an environmental ethic. For years we have been fostering within children the concept that you "don't pick the wildflowers." This same principle can be immediately established along our maritime borders with the wildflowers being transformed to the anemones within our greatly endangered intertidal areas.

Programs seeking to foster positive attitudes should begin in kindergarten and continue through the graduate level. Currently there are negligible efforts in developing programs that inculcate the concept of an environmental ethic.

Horatio Algerisms still persist: "Some day someone will find the perfect solution to all our pollution." We can't afford the luxury of the "ostrich syndrome." We know the problems are there. The mass media belabor them; our eyes, noses, and ears constantly remind us of them. It's unfortunate that the Twainian observation remains true: "Everyone talks of the problem but no one does anything about it."

FOR several years, Donald A. MacLean of the San Diego Department of Education and I have examined many of the curricula being employed nationally in the marine sciences. We have found that nearly all of the materials that are currently being written are highly structured and patterned somewhat after what classically could be expected of the Scripps Institution of Oceanography or Woods Hole. In many instances this type of curriculum does not offer enough relevancy for the average student and eventually is offered to only the more able college-bound student or as an after-school science activity.

We believe that certain curricular changes are necessary for marine science instruction for two reasons: One, instruction in the marine sciences simply will not receive financial support in the school districts on the basis of being just another course requiring somewhat special facilities and an additional budget for teachers and materials. Second, the marine sciences must be considered part of a larger study of man and environment in order for students to see relevancy.

Substantial numbers of today's school-age youth are not able to grasp the relevancy of their science instruction to their own lives, present and future. Others have a vague half-articulated notion that science is a threat to individual welfare. Most possess striking amounts of scientific facts, but are not able to venture beyond the informational doors of their science textbooks, periodicals, radios, television, and typical classroom instruction to an understanding of the fundamental concepts which lie behind all science information.

Some of the present and uneasy concerns about science may come from the deep-seated feelings of youth that they have little control over the events of their own personal lives. Modern science technology does indeed permit the destruction of huge cities within minutes. Impersonal paper-and-pencil tests administered by strangers and scored by giant machines often determine whether or not one is admitted to a college or finds suitable employment. Science technology has provided many things which have made man's life longer and more enjoyable than in ages past. Unfortunately, short-term gains have too often been made by technology at the expense of long-term losses for mankind. Students need not be very sensitive to be aware that many of our nation's technological activities have destroyed lakes, rivers, air, and recreational space.

The days of youth pass quickly into young adulthood and all adults should be guided to ask themselves daily what influences their many activities have upon other men and upon our planet's environments.

We suggest that marine science courses exploring the human animal in respect to (a) physiological structure, (b) fundamental conditions necessary for life on earth (food, water, temperature needs, breathing gases, etc.), and (c) desirable conditions for man (suitable gravity, humidity, feelings of security, other personal comforts, etc.) be introduced at all levels of the educational spectrum. Follow this instruction by guiding students through exploration of values which are basic to all men. Consider the possibility of helping youngsters evaluate human behavior in respect to eight basic values: respect, power, wealth, enlightenment, skill, well-being, rectitude, and affection. Students can be guided to understand that deprivation of one or a number of the eight values can be damaging to both man's physical and mental health. Individuals have status in society in each of the eight values according to their degree of achievement; the degrees of status in our society range from severe deprivation to high indulgence.

We would further suggest that, as each student begins his study of his local environment, he first consider the many different people who use the environment. Then, he should select or be assigned a particular role—politician, land developer, biologist, recreationalist, etc.—that is typically found within the local area and be required to view each aspect of the marine sciences from that posture for the semester. As each subject area is completed, at least one school period should be used for an in-depth discussion of how each person in a particular role views the subject area under study.

A final examination, then, could consist of each student's being assigned an entirely different role or a series of roles from which to evaluate how he would carry on responsible uses of the environment in certain hypothetical situations.

TODAY, in education, we are faced with many innovations which appear quite attractive. They are appealing because they are different and possess many innovative qualities by which they may stimulate a few students to achieve beyond the levels which were previously set for them. Seldom, however, do we find an innovation which possesses almost universal appeal to both the academic and non-academic oriented student and which enables the classroom teacher to take the child where he is and provide a singular experience which can stimulate and motivate attitudinal changes.

Children today, because of exposure to mass media, are thought to have been made aware of their world. However, when students touch their first live fish, they glow with excitement and become totally involved in finding out what's inside its mouth or under its gill cover. One realizes then that what past generations took for granted has become a phenomenal, new experience for the youthful, urban population. Contrived experiences within the classroom can never replace the true discovery methods so vital to motivating students.

RECOGNIZING that students must have increased opportunities to come to grips with their real world, however distant, the Orange County Marine Science Floating Laboratory program began in 1967 with the major goal of allowing children to actively participate in real science.

The program began as a pilot program under a grant from E.S.E.A. Title III.[1] The purpose of the pilot program grant was the establishment of an organization to develop a floating marine laboratory program to explore the feasibility of using a sport fishing boat to supplement the existing science curriculum.

ORANGE COUNTY SCHOOLS
FLOATING MARINE LABORATORY
FURY II

Aboard the FURY II, students are given the chance to engage in scientific research.

The pilot efforts proved very successful and upon application to the United States Office of Education a three-year operational grant was approved in June 1967.[2]

The program has developed the concept of "A Hands-On Practice of Science" as its theme. That is, each and every student participating on board the FURY II, The Floating Laboratory, participates. They learn by doing. Students are exposed to the scientific world by placing them in an environment which allows them to practice science by "doing" science.

Already, many positive gains have been derived from the program. The further support of a multidisciplinary approach to science ranks high. Allowing the students to apply the concepts of biology, physics, and chemistry to a meaningful experience may well foretell the ways of science education in the near future.

Another positive feature of the program is the inservice training of the classroom teachers accompanying their students. The trips stimulate them to become better informed about this environment and its potential as a teaching tool. Also we have found that during the teacher orientation cruises, held before the fall and spring semesters begin, the teachers remark that they have had to review many of the basic concepts of their major area of college work.

Man's attitudinal alterations must come from new educational opportunities, explorations, or inquiries into real experiences of the world in which he lives. American education today provides the optimum opportunity to develop programs aimed at inculcating an environmental ethic. An attempt is being made in the southern California area to break the classical patterns of education and direct the attitudes of students toward a positive appreciation of the marine environment. ☐

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[1] (P.L. 89-10; Grant No. 66-2278)

[2] (OEG-3-7-703799-4257; Project No. 67-3799)

Organizing Outdoor Classrooms

in the Park System

K. T. KELLERS

Chief Naturalist
Monmouth County Park System
Freehold, New Jersey

THE Monmouth County Park System, located in central New Jersey, carries on a cooperative environmental education program with school districts in the county. The Park System provides the study areas and resource people, and the school districts carry through with the educational process.

This cooperative venture has spurred a number of local schools into utilizing outdoor areas adjacent to the school grounds. The Park System has supplied resource people to schools in planning their outdoor classrooms, but it has not been able to meet with each school district on a day-to-day basis in order to complete a well-planned outdoor classroom that takes best advantage of existing natural areas.

Unfortunately, there are few models that can be used to organize data and help establish an overall environmental education program. Environmental information must be gathered. Systems must be organized that allow proper management of outdoor areas. Information must be distributed to the teaching and administrative staff, and scheduling must be planned. The resulting program must provide a unique opportunity for school personnel, yet not require the use of new funds or elaborate physical facilities. The following outline is suggested as an aid in establishing outdoor study areas.

THE INITIAL step in such a development is to define clearly the property in question. From field observation and visits to the local tax maps, property boundaries can be determined and then indicated on the pertinent quadrangles of topographic, geologic, and soil survey maps. Location of the tract in the community and on the aforementioned maps insures that planning and interpretation may be kept in perspective to community conditions.

Information concerning the topographic features, geologic formations, drainage, soil series, and recommended agricultural land uses has already been assembled by state and federal authorities. Utilization of the standard U.S. Geological Survey (USGS) topographic maps distributed by the Department of the Interior, Washington, D. C., provide basic landmark, topographic, and elevation information needed for a given quadrangle. Soil series, slope, erosion, and land classes have been compiled by State and Federal Soil Conservation Services under the direction of the United States Department of Agriculture. The occurrence and nature of important geologic formations and their age and condition have been compiled by state geologists as part of the ongoing activities of the USGS.

It remains, therefore, to contact the necessary agencies and compile the pertinent basic information for utilization by classroom teachers in their environmental education activities. In-

Overnight camping as a culminating activity in environmental education.

Working at a collection site.

cluded in such a compilation of raw data should be an index describing the habitats that make up a given property. This information usually can be gathered by local residents or consultants and public agency resource people trained along these lines. Plant, bird, and animal lists will also be needed in order to sketch an overall picture of the biomes that compose the ecosystems found within the natural area.

Aerial photographs and 200-foot-scale maps of the land mass should also be acquired. In many cases, aerial photographs can be obtained from local sewerage groups, planning boards, and zoning commissions. These photographs are ideal for locating existing roads, trails, streams, and clearings that may not appear on official maps. It is an easy matter to transfer the information to the 200-foot map. The 200-foot map is essential for planning the use of small parcels of land, up to 1,000 acres. Larger tracts require a smaller scale in order to provide an easily manipulated map.

The 200-foot scale map is utilized for locating the various habitats and places of high esthetic value found on the property. Contours are necessary, as their location serves as an aid to defining the habitats that have been located and surveyed. These areas are color coded and filled in with contrasting colors; thus the habitats are easily located for proper planning of trails and gathering areas for class instruction. That work is easily done on an acetate overlay using the many kinds of water-soluble marking instruments on the market.

The program planners must next describe on the habitat map the many kinds of habitats found in the natural area. Some will appear several times, others only once. Some, because of the nature of the environment, will support a great variety of life forms, others will not. In order to utilize the entire land tract to its full potential, it is important that the habitats be classified according to their ability to support life and to withstand the stresses that will be placed upon them as environmental studies begin to take place. For example, a pond and stream provide good opportunities for collecting specimens; the watery environment supports a wide variety of plant and animal life that quickly repopulate the biological community. Other habitats could not withstand any collection without causing irreparable harm to the ecological relationships indigenous to the ecosystem. Some may support a bit of careful traffic for observation and measurements. The Park System has used these three levels of classification for scheduling purposes. The criteria we have used to identify collection sites, measurement sites, and observation sites include the following:

1. The intrinsic ability of a habitat to support life, taking into account the current environmental factors such as rainfall, temperature, and past use
2. Presence of rare specimens
3. Number of other habitats on the tract that effectively reproduce the conditions found in the habitat under question
4. Flowering dates and the development of seed

It necessarily follows that the habitats that are exposed to stress should be duplicated on the land tract so that some will be in service while others will be at rest. It may be necessary to allow some types of habitats to remain out of service several years before being again exposed to stress. It may be feasible to reclassify these areas as observation

A group utilizes an observation and measurement site.

sites. The reason for reclassification could be a part of the overall educational plan.

IT IS especially important to plan for access routes to the outdoor classrooms and laboratories (habitats) so that classes may easily utilize the area, but yet not disturb important features en route. Basically, a somewhat wide stem trail may be constructed (or rather pruned) through the entire property. This trail should follow a route that does not cause destruction of important features, but yet follows a route that is in close proximity to each habitat. Smaller loops may then detour off the main stem trail to embrace each classroom along the route. A series of rest sites, or group collection sites should be located along the stem trail so as to insure that brief discussions of observations and results can take place.

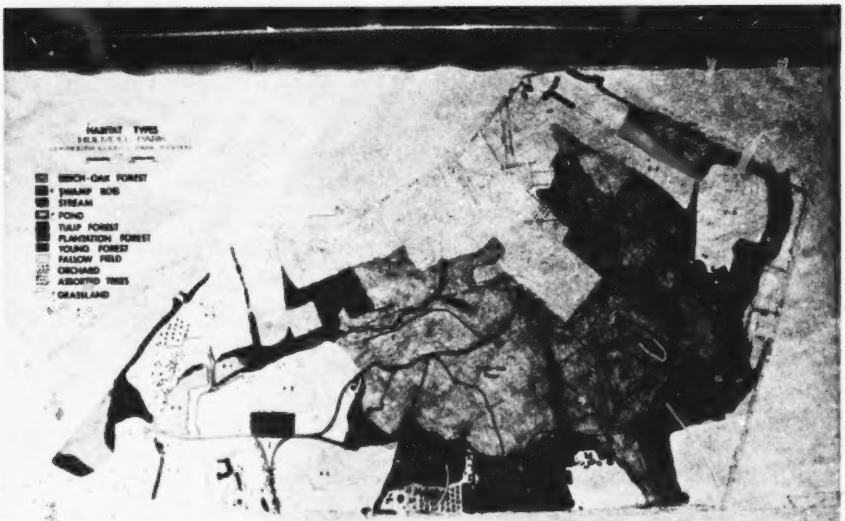
Once the "classrooms" have been located and classified, it remains to organize a filing system, coded to the base map and classification system to be established. Such a system provides a ready repository for (1) subjective field notes concerning the physical condition of a habitat, (2) notes concerning data received from groups that utilize the study area, and (3) information concerning observations that determined its past classification. Periodic review and revision of such a system allows for efficient management of the land area.

Programing for use of the established classrooms is the final phase of the overall project. It has been our experience that most classroom teachers have a real desire to utilize the outdoors. Unfortunately, many do not know how to take best advantage of the tools of the outdoors. Some projects have attempted to overcome such a problem by establishing "schools of the outdoors" with their own staff. The problem with this approach is that it can service only a limited number of students, the limiting factor being its own autonomous staff. The Monmouth County Park System is attempting a somewhat different attack on the problem. For example, an interested teacher may call into the offices requesting assistance. The logical starting point here is the tried and true guided nature walk using one of our staff naturalists. The difference with this nature walk is that it is not "canned" nor does it fit into a rigid program. Suppose the teacher points out that her class is studying animal homes. The nature walk for that class, then, is themed about that idea.

Over a three-year period, the teacher utilizes the natural areas and the park staff acts as resource people. She learns over that time what to see, hear, or look out for and becomes generally aware of the outdoor classroom. In the fourth year, this same teacher may then simply schedule the classroom she requires to undertake a particular activity. The park personnel can then be shifted to provide aid for a new classroom teacher. Such a system could be utilized by local school districts oriented about an outdoor study area and a small group of trained teachers.

This simple system requires no outlay of extra funds as it calls for more effective use of public lands and materials under park and school district ownership. It takes advantage of existing data, provides for a logical sequence of acquiring raw data pertinent to any outdoor study sites in question, and provides plans that enable classes to take full advantage of the special features that any area can afford. Finally, efficient use of existing personnel places each natural area within the grasp of every classroom teacher, providing an opportunity for every youngster to "visit a nearby pond." □

A 200-foot scale map with habitat areas color coded and existing trails located. Note how the stem trails allow initial access to certain habitat areas. Subsequent trail development will call for loops that will take advantage of special situations within a particular habitat area.



PART IV

STUDENT ACTIVITIES

Research projects and classroom ideas

BACTERIAL POLLUTION IN WATER: ADAPTING STANDARD METHODS TO THE CLASSROOM

Bernard I. Sohn and R. Eugene Bullock

Bacteriological Chart

FOR all the esoteric prose that has been printed on the subject of bacterial pollution in water, the single most important biological indicator of water pollution is a simple, very common class of organisms known as coliform bacteria.

As one bacteriologist put it: Looking for bacteria in water is like looking for pigs in the dark; it's easier to find the pig that squeals. This, he explains, is the reason sanitarians and other water-pollution analysts first look for the relatively harmless coliform bacteria in water rather than for the real troublemakers: disease-producing organisms that pose a real threat to human health.

The attribute that makes coliform bacteria so easy to detect is their special ability to break down a complex "sugar" called lactose to form several simpler substances, one of which will combine with a fuchsin stain to form an iridescent green coating over the growing coliform colony. These colorful "sheen" colonies are easy to distinguish from their less colorful fellow travelers (the pigs that don't squeal).

There are other reasons, though, for the choice of coliform as the official criterion of the sanitary quality of water. First of all, coliform bacteria usually originate in the intestines of warm-blooded animals, including man. Therefore, their presence in water in *unusual* number is cause for concern, since human wastes are the most likely source of organisms pathogenic to man, such as those that cause typhoid fever, dysentery, or cholera. Coliform bacteria are also hardier than most pathogenic organisms, thus it's unlikely that the pathogenic species are still surviv-

Mr. Sohn is director of the Educational Division, and Mr. Bullock is technical information editor of the Millipore Corporation, Bedford, Massachusetts.

ng after the coliform have all died off. Coliform grow readily at room temperatures (70 to 80°F), so samples can be cultured easily without a laboratory incubator. In many countries, where water has to be tested far from existing laboratories, the analyst may even incubate samples by taping the petri dish to his body.

The simplest, most widely used test for coliform bacteria consists of filtering a water sample through a bacterial retentive membrane filter. The microscopically small filter pores let the water through, leaving microscopic life trapped on the filter surface. To count coliform bacteria, the analyst puts the filter on a pad soaked with a suitable nutrient medium, and the nutrients wick up through the filter pores to keep the microbes fed and multiplying. The liquid nutrient also contains the lactose and stain that advertise the presence of coliforms. Within 24 to 36 hours, each microbe becomes a colony of billions, visible even without a microscope.

The mere presence of coliform colonies, however, does not prove that the water is "polluted," because all open bodies of water are exposed to animal excretion and seepage from the soil. *What is important in assessing probable pollution of water is the number of coliform in the sample.* When health officials find the number exceeding standards set for certain areas and types of water, they assume that disease-producing bacteria are also present. Further tests are then performed to isolate and culture the pathogens.

A local pond or river can furnish abundant opportunities for microbiological investigations, including those for coliform organisms. With minimum supervision, even beginning biology students can perform these tests with the aid of a membrane filter and a simple vacuum filtering apparatus that can be constructed at home or purchased inexpensively.[1]

Outlined in the paragraphs that follow are the details of a procedure for isolating and culturing coliform bacteria that is very similar to that used by professionals in analyzing water pollution.

1. Sterilize a plastic autoclavable filter holder in an autoclave or by immersing it in boiling water for three minutes. If this is not practical, as in a field experiment, dip the filter in 70 percent isopropyl alcohol (rubbing alcohol) for a few seconds, shake it off, and let it air dry. The alcohol can be bought at a drug store or supermarket.
2. Load the filter holder (Figure 1) with a Type HA (0.45μm pore diameter) membrane filter. Be sure to handle the filter with smooth-tipped (nonserrated) forceps that have been sterilized by dipping in alcohol.
3. Place a sterile absorbent pad in a 47 mm petri dish. Absorbent pads are disks made of material similar to blotter paper and are supplied in the same envelope with the membrane filters.
4. Break open an ampoule of MF-Endo medium,[2] and pour the entire contents (2 ml) onto the absorbent pad. (Figure 2) As an alternative, you can prepare a stock solution from powdered MF-Endo medium and pipette 2 ml of this solution onto the absorbent pad. Close the petri dish and set it aside until Step 8.
5. To the funnel, add about 20 ml of sterile water or tap water that has been boiled for several minutes. The exact volume added is not critical. Its purpose is only to evenly disperse the bacteria in the measured sample.
6. Pipette an aliquot of sample water from a pond or stream into the funnel. Swirl it in the funnel to mix the sample with the sterile dispersion water. The size of the aliquot will vary with the contamination level of the water being sampled. To determine the best sample size, start with 1 ml. After you grow the first culture, you will

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[1] One such system is the Sterifil (Trademark of the Millipore Corporation) System available from the Millipore Corporation, Bedford, Massachusetts.

[2] MF-Endo medium is a culture medium that is selective for coliform. It contains lactose broth and a fuchsin-sulfide complex. Skin or clothing accidentally stained with MF-Endo medium can be cleaned with a dilute solution of sodium sulfite or household bleach, followed with soap and water.

Figure 1. Use smooth-tipped forceps that have been sterilized in alcohol to insert the membrane filter into the filter holder.

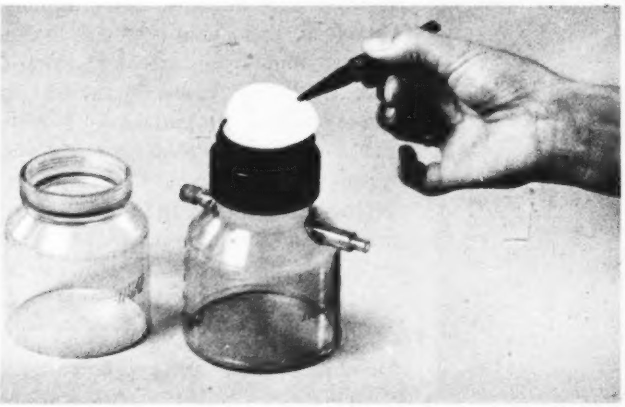
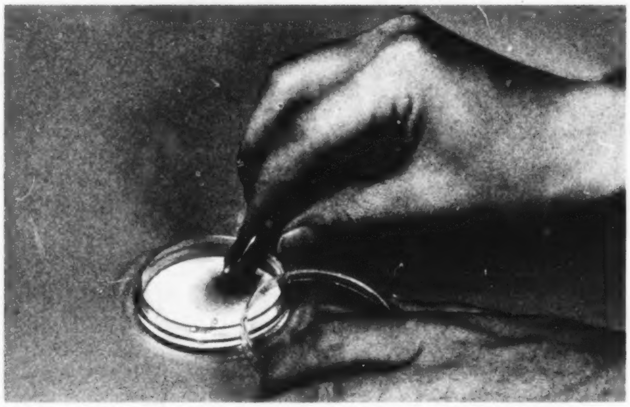


Figure 2. Culturing dishes can be prepared quickly by emptying a 2 ml glass ampoule of nutrient medium on an absorbent pad.



be able to tell whether a larger or smaller sample would be better. Adjust the sample size to get no more than 20 to 80 coliform colonies on the filter surface. The total number of colonies, including coliform, shouldn't exceed 200. (See Figure 3.) Another method is to try 0.1, 0.5, 1, and 2 ml in the first experiment to determine the optimum sample size.

To determine coliform levels in different sources, the following sample sizes are recommended, as a general rule:

- For untreated water (fresh or salt), add 1 ml of sample to the dispersion water prepared in Step 5 above.
- For well water or natural spring water, use 50 ml and omit Step 5.
- For chlorinated tap water, use at least 500 ml and omit Step 5. You will have to filter in several steps if the receiver flask holds only 250 ml. If the school laboratory has an aspirator or vacuum pump, you can filter the entire sample at one time by attaching the top portion of the filter unit to a standard one-liter filtering flask. (See Figure 4.) Ideally, drinking water should be free of coliform bacteria. If you do find more than 4 per 100 ml, then it is likely that this contamination is from faulty technique rather than from polluted water.

7. Using a hand vacuum pump (Figure 5) or some other suitable vacuum source, such as a water aspirator, apply vacuum to the receiver flask. This will force water to flow through the filter, leaving the bacteria trapped on the filter surface.
8. After filtering the test sample, release the vacuum by removing the vacuum-pump tubing from the side-arm of the receiver flask. Unscrew the funnel, and use alcohol-dipped forceps to lift the filter membrane. Place it grid side up on the saturated absorbent pad in the petri dish. (Membrane filters are imprinted with grid lines to facilitate the counting of colonies.) Carefully line up the filter with one edge of the petri dish and set it down with a slight rolling motion so it is evenly centered. Close the petri dish tightly.
9. Invert the petri dish and incubate the culture for 48 hours at normal room temperature, or 24 hours at 37°C in an incubator.

   The medium will supply all areas of the test filter with needed nutrients, diffusing directly through the filter to the microorganisms on its surface. The petri dish must be inverted because incubation often causes moisture condensation inside the closed dish. If the dish were right side up, droplets could form that might fall onto the filter surface, spoiling the appearance of the developing colonies. After the colonies have developed, turn the dish right side up, remove the test filter, and allow it to dry on a clean blotter or some other clean absorbent surface (paper towel) for one-half hour. Reclose the dish, and put it aside carefully for sterilization or disposal.
10. With a hand magnifier or low-power microscope (10X), scan the surface of the filter for colonies having a shiny, greenish surface. Count the total number of these "green sheen" colonies on the filter.

Calculations. The official way of expressing coliform levels in water is in terms of the number of coliform per 100 ml.[3] Bear in mind that each colony observed developed from a single bacterial cell in the original sample. To figure the number of coliform bacteria present in the water tested, use the following formula.

$$\frac{\text{No. of Coliform Counted} \times 100}{\text{Milliliters of Sample}} = \text{No. of Coliform/100 ml}$$

Example: A two milliliter (2 ml) sample was added to the filter funnel which contained approximately 20 ml of sterile water. After filtration and incubation, 48 green sheen colonies were counted on the filter.

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[3] Standards vary from one municipality to the next. Check with your local officials to determine what the standards are for your area for different types of water (raw water, well water, drinking water, and public swimming areas).

Figure 3. Grown on a membrane filter with MF-Endo medium, the coliform colonies acquire an easily distinguishable sheen.

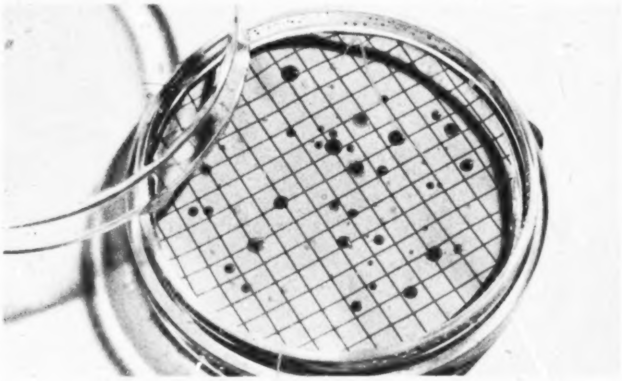
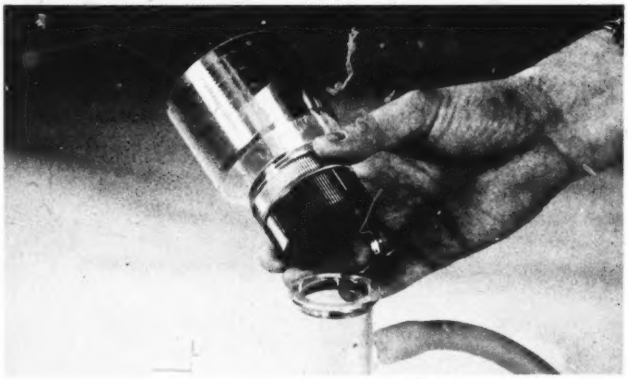


Figure 4. The top section of the Sterifil apparatus will also fit a standard one-liter filtering flask.



Therefore, $(48 \times 100)/2 = 2400$ coliform per 100 ml.

IN some cases, students conducting a water survey may wish to preserve the results of their experiment for future reference or to attach to a report. Here is a way this can be done:

1. Saturate a piece of blotting paper or an absorbent pad with a solution of:
   20 parts glycerine
   40 parts formaldehyde
   40 parts water
2. Using forceps, take the specimen filter from the petri dish and set it down on the saturated blotter pad for at least 2 minutes.
3. Remove the filter and let dry on a clean, dry blotter pad.
4. The dry filter can now be preserved between glass slides (Figure 6) or carefully enclosed in an envelope of plastic food wrap.

THE techniques described are simple enough to be performed by a student with minimal manipulative skills. Yet, the question of safety from possible biological infection is an important one and bears consideration. The fact that the membrane filter will trap every single organism on its surface means that if the water contains pathogens, they, too, will be trapped, along with the coliforms. However, the conditions under which these tests are performed (i.e., incubation on MF-Endo medium at room temperature) will discourage the growth of these pathogens. Only the harmless indicator organisms (coliform) and perhaps a few other innocuous gram-negative rods can withstand this "less-than-ideal" culturing environment. Therefore, the likelihood of culturing pathogens is quite remote. In spite of this reassuring fact, the teacher should make a point of cautioning students to use reasonable care in working with live microorganisms. **Whether on filters or in any other medium, all cultures should be considered potentially dangerous and treated with respect.** After the experiment is finished and results observed, destroy or deactivate the cultures that have not been preserved. Boil or autoclave glass petri dishes. Plastic petri dishes that are normally used with membrane filters may be resterilized as follows:

1. Carefully remove the petri dish covers by prying with the back of the flat-bladed forceps. Put the covers and dishes (with cultures) into a large beaker or pan containing undiluted liquid household bleach for 10 minutes.
2. Then remove the petri dishes using tongs or a rubber glove. Rinse well under running water. Put wet pads and filters into a plastic bag and discard them.
3. Immerse the petri dishes and covers in a solution of 70 percent alcohol for 10 minutes.
4. Remove the dishes and covers and stack them on a clean surface to dry. Assemble the dishes and covers. They are now ready for use.

Students can also study a variety of freshwater and marine microorganisms using this same procedure with other culture media. A good deal of research work has been carried out and published by professional microbiologists on the use of membrane filters. The following bibliography will be helpful in planning additional projects in water microbiology. ☐

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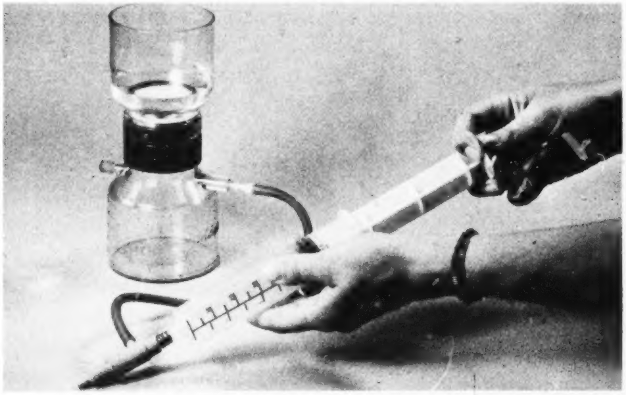


Figure 5. Applying vacuum to the flask forces water through the filter, leaving the microorganisms stranded on its surface.

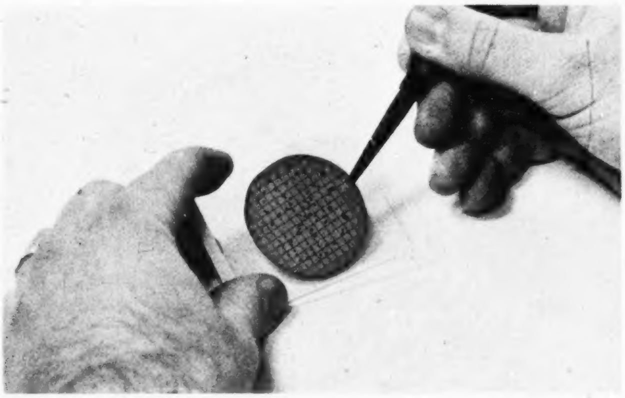
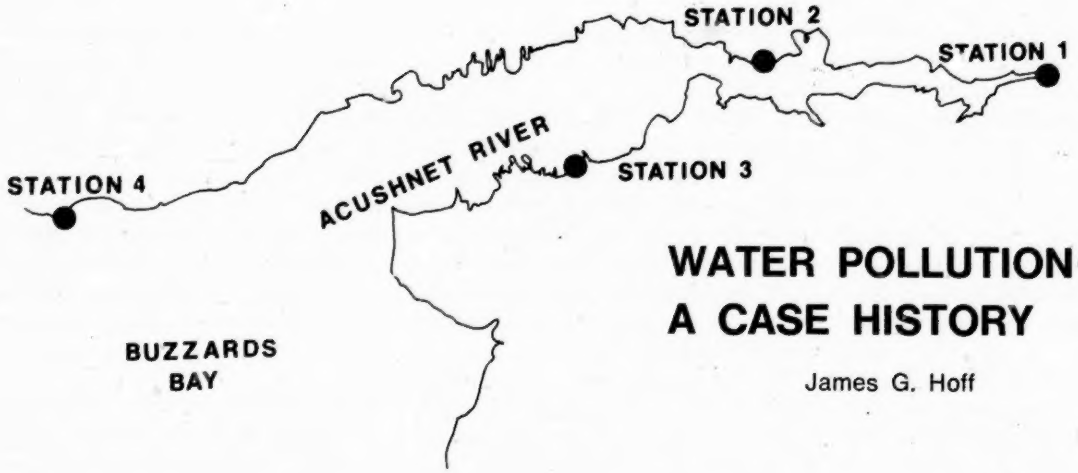


Figure 6. The student can preserve his results by mounting the dried filter between glass slides or in plastic food wrap.



WATER POLLUTION— A CASE HISTORY

James G. Hoff

THIS is a study of domestic water pollution, undertaken to further environmental understanding. The students were college biology majors, though high school students in several science courses could also make such a study. The scope of the study might change, some accuracy might have to be sacrificed, but the principles and relevancy of the material would remain. Since everyone contributes to the domestic waste problem, all students find themselves polluters. In this study we were concerned with parameters that indicate sewage pollution.

The distinguishing feature of this learning experience is that it concerned contemporary problems. It involved hard work and indicated that the way to discovery is challenging and difficult and requires cooperation and self-sacrifice. The problem is still unresolved, but it is now better understood. Most important, a valuable source of information was identified and is available for the entire community.

Area Description

The Acushnet River is tidal, approximately five miles in length, and flows between New Bedford to the west and Fairhaven and Acushnet to the east, eventually terminating in Buzzards Bay, Massachusetts. It is home port to one of the East Coast's largest ground fishing and scallop fleets. It has heavy and light industries on its banks. It is beset with varied domestic and industrial pollution problems. The untreated wastes of approximately 200,000 people enter the watershed daily.

Total Microbes

Estimates on the total microbial population were among the first tests to be applied to water bodies in order to determine the nature and extent of their pollution. Total microbial counts have been essentially ignored as diagnostic methods for the past three decades in favor of coliforms. While the preoccupation with human sewage as a polluting agent is largely justified, the total microbial count still has merit as a measurement of total organic matter in water systems. Microbial count is of value where the concern is with eutrophication rather than with disease transmission.

Table 1. Total microbe count and dates collections were made.

Location	Date	Total Microbe
Station 1	3-20-70	1.8
	4-19-70	2.2
	4-30-70	2.3
	5- 7-70	2.1
Station 2	3-20-70	2.4
	4-19-70	3.7
	4-30-70	4.1
	5- 7-70	1.6
Station 3	3-20-70	0.1
	4-19-70	1.8
	4-30-70	1.2
	5- 7-70	1.2
Station 4	3-20-70	0.1
	4-19-70	0.5
	4-30-70	0.7
	5- 7-70	0.8

Various media exist for the rearing of the total microbial fauna. In this study the agar used was the Plate Count Agar (Tryptone Glucose Yeast Agar). Plastic disposable petri dishes make ideal environments. The cultures are diluted, adjusted to a pH of 7, and incubated at 35° C for 24 hours. In the counting process, only plates showing between 30 and 300 colonies were considered, and all plates which fell within this range were averaged into the final count for each sample.

Total microbial accounts above 1 million are indicative of polluted inshore waters. The data obtained in the study, in general, clearly indicated organic pollution. But more important, they indicated that the major sources from which organic wastes were entering the river in the upstream section were near stations 1 and 2. (See Figure 1 and Table 1.)

Coliforms

The isolation of pathogenic bacteria or any microorganism from water is not recommended as a routine practice inasmuch as the techniques available are tedious and complicated. The results are not of major significance and may be confusing in a particular study of pollution.

For many years the coliform group

Dr. Hoff is an associate professor of biology at Southeastern Massachusetts University, North Dartmouth.

of bacteria has been used to indicate the pollution of waters. Full discussions can be found in most texts on bacteriology. Experience has established the significance of coliform group densities as criteria of the degree of pollution.

The membrane filter technique, which provides a direct plating for the detection and estimation of coliform densities was employed in this study.

The Division of Water Pollution Control of the Commonwealth of Massachusetts has established water quality standards for marine and coastal waters. The lowest acceptable class (SB) for bathing and recreational purposes is defined as "the acceptable coliform counts not to exceed a median value of 700 and not more than 2300 in more than 10% of the samples in any monthly sampling period." Stations 1, 2, and 3 are clearly grossly polluted and do not meet the class (SB) requirement (Table 2). The New Bedford beaches are near station 4. The data are not sufficient to accept or reject this area as class (SB). However, the data indicate that continuous monitoring is necessary if public health problems are to be avoided. With such a massive source of contamination near a recreational area, coupled with higher summer water temperatures, the proper set of conditions might give rise to drastic elevations in coliform count.

Benthic Invertebrates and Sediments

Each of the four stations varied ecologically as to the progressive differences normally established for an estuarine river system from the freshwater head region to the euhaline mouth. The invertebrate faunal sampling was done on a random qualitative basis in association with sediment and salinity sampling.

The purpose was to look for biological indicators or organisms that would reflect an index of water pollution. Biological indicators include the presence of certain plants and animals which experience has shown to be significantly characteristic of kinds and degrees of pollution; they may also refer to the absence of organisms known to be highly intolerant of polluted conditions.

Station 1 was characterized by numerous fresh-water pollution indicator organisms. To name a few: *Sphaerotilus*, sewage fungus; *Tubifex*, sludgeworm; *Chironomus*, blood worm; and *Asellus*, sow bug. Sediment samples from Station 2 are characteristically layered with one to two inches of oil over an inch of silt. The number of individual organisms as well as species collected here is very small, and the evidence of pollutional restrictions is overwhelmingly evident. Over 98 percent of the samples contained no living macrobenthic organisms. Station 3 shows increasing species variation, with a small number of more tolerant polyhaline species as the dominant members of the benthic organisms, and a correlated factor of species absence with proportional intolerance. Station 4 demonstrates the more indirect effects of organic pollution, by accentuating the "indicator by absence" principle and relating the limiting effects of marine pollutional changes to a larger community.

Biochemical Oxygen Demand

Biochemical Oxygen Demand is the measurement of the oxygen utilized in the stabilization of the organic matter in sewage by microorganisms over a five-day period at 20°C. The rate of oxygen depletion depends on the amount of oxidizable organic matter and the number of microorganisms. This rate will determine the BOD value of the water sample. There are numerous problems that arise in determining the BOD. A few are: (a) photosynthesis by algae, (b) acclimation of bacteria, (c) sample dilution, and (d) toxic substances. The understanding and the controlling of these parameters give the student an opportunity to encounter problems that are fundamental to population ecology.

BOD bottles were used for the collection of samples, and the dissolved oxygen was determined by the sodium azide modification of the Winkler method.

Table 2. Coliform and Streptococcus concentrations in the Acushnet River.

	NUMBERS OF VIABLE CELLS PER 100 ML		
LOCATION	DATE	COLIFORM	STREP
Station 1	2-19-70	120,000	200
	3- 4-70	170,000	400
	3-20-70	22,000	400
	5-16-70	120,000	200
Station 2	2-19-70	13,000	4,900
	3- 4-70	550,000	90,000
	3-20-70	380,000	14,000
	5-16-70	120,000	800
Station 3	2-19-70	4,600	200
	3- 4-70	600	65
	3-20-70	2,000	400
	5-16-70	1,600	200
Station 4	2-19-70	700	65
	3- 4-70	15	5
	3-20-70	170	25
	5-16-70	200	25

Table 3. Biological oxygen demand values in the Acushnet River. Station 2 values are comparable to sewer influents.

LOCATION	DATE	BOD—PPM
Station 1	3-20-70	2.96
	4-16-70	2.25
	4-21-70	2.14
	5- 7-70	2.50
Station 2	3-20-70	27.35
	4-16-70	70.50
	4-21-70	95.50
	5- 7-70	95.70
Station 3	3-20-70	5.50
	4-16-70	11.10
	4-21-70	10.90
	5- 7-70	10.70
Station 4	3-20-70	8.66
	4-16-70	11.75
	4-21-70	11.60
	5- 7-70	10.90

Table 4. Concentration of nitrates.

		ug at/l*	
LOCATION	DATE	NO_2 - N	NO_3 - N
Station 1	2-16-70	0.12	< 30
	3- 4-70	0.20	< 30
Station 2	2-16-70	0.43	7.17
	3- 4-70	1.48	26.52
Station 3	2-16-70	0.44	7.66
	3- 4-70	0.18	2.52
Station 4	2-16-70	0.10	2.40
	3- 4-70	0.07	1.33

* Microgram atoms per liter.

Table 5. Concentration of phosphates.

LOCATION	DATE	INORGANIC-P ug at/l*
Station 1	2-16-70	.940
	3-18-70	.254
	5- 4-70	.244
Station 2	2-16-70	1.52
	3-18-70	9.40
	5- 4-70	5.08
Station 3	2-16-70	2.67
	3-18-70	2.30
	5- 4-70	1.07
Station 4	2-16-70	.583
	3-18-70	.343
	5- 4-70	.418

The New Bedford sewer system was constructed in 1852. Since 1917 an interconnecting sewer line has been in operation which is supposed to funnel all the raw sewage beyond station 4. However, direct outfalls do occur along the river.

The BOD values in the Acushnet River are extremely high (Table 3). In fact, some of the upriver values are comparable to raw sewage influent concentrations. At Station 2, dilutions of 2 percent were used to obtain valid readings. This dilution alone classifies this water as raw unsettled sewage. At Station 3, the sample dilutions were from 25 to 50 percent, which is comparable to sewer plant effluents of primary treatment (screening) only. No other parameter in the study was more significant to the class. Here, the terms self-purification, eutrophication, and sewage overloads had meaning.

Inorganic Nutrients

Many techniques are available for the determination of nitrates and phosphates in water. One technique employs a portable kit which is ideal for the high school where time and funds are limited. In this study phosphate-phosphorus was analyzed according to the ascorbic acid, single solution method; and nitrate-nitrogen, by the cadmium amalgam method.

Limiting values as well as pollution levels for inorganic phosphorus and nitrate concentrations in aquatic ecosystems are widely covered in the literature. The immediate salient feature of the inorganic nutrients is the extremely high values in the mid river section (Tables 4 and 5). These values are from five to ten times those found in adjacent waters of Buzzards Bay. The values compare to the highly polluted Hutchinson River area in New York and seem to be the expected values in the more and more commonly occurring eutrophicated Northeast Coast estuaries.

In Retrospect

Traditionally we have never understood or even been interested in the ecological effects until after they are produced. Basically the situation is this simple: Our ability to pollute and disrupt has far outdistanced our ability to understand what we are doing.

Man is experiencing environmental deterioration daily because natural environmental systems are not able to absorb or recycle the increasing waste products produced almost indiscriminately by human populations. The side effects of Western civilization's technology have been rather large-scale interruption and destruction of environmental systems, the very systems upon which we, and all living things, depend. The realization that we must face is that to continue such conflict with environmental systems will force us to compromise even more drastically between our standard of living and our survival. We are at the beginning of a new phase of man's history when he must face ecological realities. He must begin in his own backyard.

Assuming that man successfully stabilizes his population, what are the keys to the success of solving environmental problems? First, the educational system must recognize the essence of the problem. All aspects of pollution must be defined and studied within the school curricula. Only in this way will a national sense of awareness evolve. Foolish activities, such as burying the internal combustion engine, and the confusion of beautification with environmental conservation not only indicate a failure of the educational system but are themselves often a waste of human energy. Studies such as the one reported here are far more meaningful and useful. Second, a land ethic as proposed by Aldo Leopold must be central to all educational experiences. Evidence of the lack of a land ethic are omnipresent. The land-water relation is still strictly economic, entailing privileges but no obligations. The employment of a river as a sewage treatment facility by an entire municipality clearly demonstrates the need for a land ethic. ☐

ACKNOWLEDGMENTS:

Thanks are extended to Chuck Townsend for the photograph, Ann Harrington for the tables, and to all participants in the seminar in water pollution.

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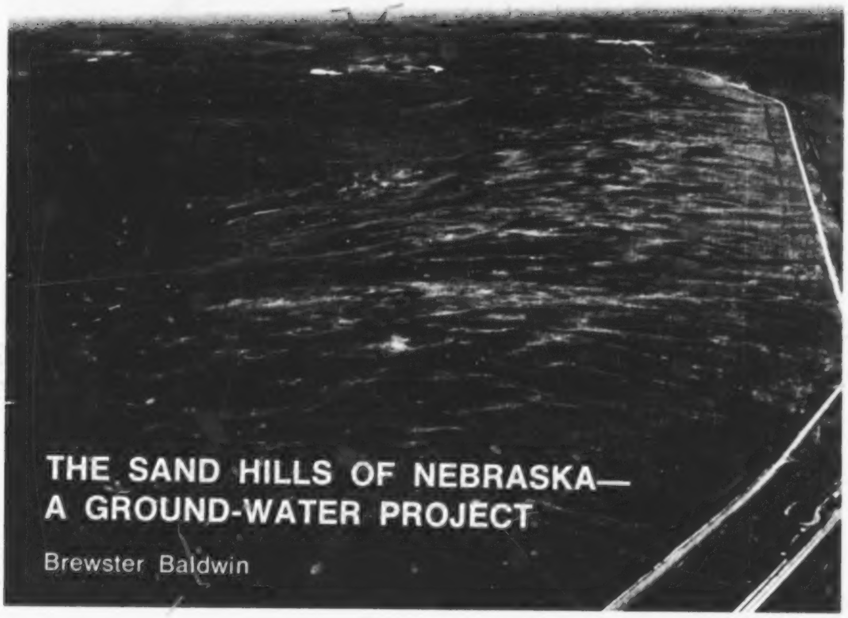
THE SAND HILLS OF NEBRASKA—A GROUND-WATER PROJECT

Brewster Baldwin



COURTESY, H. T. U. SMITH, UNIVERSITY OF MASSACHUSETTS

Figure 1. Looking west from Ashby. The dune ridge ranges from 200 to 300 feet in height.

GROUND water is important in areas that have no lakes, surface reservoirs, or aqueducts, and it will play an increasingly important role in water management of the future. [4] Clearly, we need to understand its behavior in order to design laws [6,8,9][1] and practices [2,3] that foster wise use of surface and ground water. Appropriately, ground water is a standard topic of earth science. Still, there is something sterile about merely having students learn to define artesian conditions, permeability, and water table; these terms and concepts seem detached, and the textbook does not provide an adequate frame of reference. The idea of ground water often does not seem real to students.

Why not? The reason is that each area is unique. Ground-water conditions vary from place to place in response to variations in climate and geology. An hour spent paging through a summary of conditions across the country [4] will make this abundantly evident. Considering all the possible kinds of conditions, it is no wonder that we have difficulty discussing this topic in the abstract.

For real understanding, it is helpful to have practical experience with a ground-water situation in some particular geographic locality. One obvious place is the school's local community. Another place is one that can be studied on maps, such as an area of glacial deposits in Wisconsin [5] or the Sand Hills of Nebraska. The Sand Hills area has an ideally simple ground-water situation. It is a giant sandbox; rain water infiltrates the dunes, seeps east, and comes out to form rivers.

Two class meetings allotted to the local water supply and four to the Sand Hills area can provide a good frame of reference for understanding the role of ground water. Three questions focus any ground-water inquiry: "In which direction does ground water move?" "How much water is available?" "What is the quality of the water?" These are questions that scientists and engineers must answer if an area's water resources are to be managed wisely.

HOW does water get to the drinking fountain in the hall? The school librarian should obtain three references, numbers 1, 4, and 7.[2] The first of these includes a discussion of water quality. A geologist from the state geological survey or nearby college can suggest reference books and reports on local geology and ground-water conditions. An engineer from the municipal water department can provide quantitative data on per capita use of water, industrial use, capacity of the water system, effluent treatment, and quality of water. He can show a map of the wells or surface reservoirs. If the school is in an area where individual wells are used, a professional well-driller might be invited to discuss ground water from his point of view. Perhaps the information from these resource people can be presented to teachers in a workshop or mini-course.

THE students may now begin the Sand Hills Project. The problem here is to determine the rate at which precipitation infiltrates the Sand Hills of Nebraska. This involves a large area and must be treated as a class project, but adequate maps and data are available as listed in the appendix to this article.

The Sand Hills mantle the upland between the Niobrara River and the North Platte River in central Nebraska. Rain seeps down through sand dunes to reach water table, recharging ground water in an unconfined aquifer. The aquifer is composite; it is primarily the Ogallala Formation, a Pliocene sheet about 400 feet thick that maintains the east-sloping High Plains, but it also includes Pleistocene valley deposits and the veneer of dunes. Ground water seeps east through the aquifer, discharging by seeps and springs into gaining (effluent) rivers that incise the Ogallala in the eastern part of the region. This is a simple hydrologic situation—ground-water discharge equals ground-water recharge.

In yearly averages, Precipitation (P) = Evapotranspiration (E) + Infiltration (I) + Runoff (R). The usable water (water yield) of an area is $I + R$; whether the water is underground or at the surface, it is all the same water. The Sand Hills project

The author teaches geology at Middlebury College, Middlebury, Vermont. The geology program is built around current problems, in place of traditional courses.

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[1] U.S. Geological Survey, Washington, D.C. 20242; free.

[2] Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402; $2, $4.50, $1.50, respectively.

allows students to quantify the equation—to determine the water yield for this region. Annual precipitation averages about 19 inches. How much of this is usable? Is it as much as 10 inches? After all, rain soaks into sand and should quickly seep below the reach of evaporation and plant roots. On the other hand, the climate is semi-arid; perhaps very little water is recharged. At least we know P.

During the project, study of maps will show that there is no surface runoff except in the east, and the students will prove that no ground water flows into the region from the west. Therefore, $P = E + I$. Can they measure I? Yes, because I seeps to the surface to constitute the water flowing in the rivers in the eastern part. The U.S. Geological Survey makes daily measurements at stream-gauging stations on these rivers, and it publishes values of river discharge (R) past the stations. In order to calculate I, students need merely establish the infiltration area that feeds water to a particular station; I times the area should equal the R at the station.

How will the students delimit the infiltration area? They need merely draw the path of ground water that seeps into the river at the station; the area inside this line is the infiltration area. How do they know where to draw the line? If they have a map showing water-table contours, this is a simple task, because ground water moves at right angles to each contour. Thus, the line is drawn (on each side of the river) upgradient from the station, curving in order to cross each contour at right angles.

Where do students get a water-table map? They make it. Their data are the hydrologic features that show in blue on topographic maps of the region. These features are "outcrops" of water table, and their elevations are the basis for drawing water-table contours.

The teacher who has not worked with water-table contours could study the Ashby quadrangle, Nebraska, which is likely to be in the set of topographic maps at the school. The lake levels are not random but become progressively lower to the east. It is reasonable to conclude that the lakes are hydrologically connected beneath the surface, and so they are water-table lakes. The 3,800-foot water-table contour starts in the northwest corner; it must continue between School Section Lake (3,811) and Alkali Lake (3,797). It extends on the northeast side of an unnamed lake (3,810), but turns south just west of Melvin Lake (3,798). A piece of string can be placed on the map to record the 3,800-foot contour, and other pieces can be added for the 3,750 and 3,850 contours. The strings represent a surface that is mostly beneath the land surface; knowing the elevation of a point on the land surface, one could estimate how deep it is to water table. Also, one could pick a point near the west edge and trace the probable path of ground water across the quadrangle.

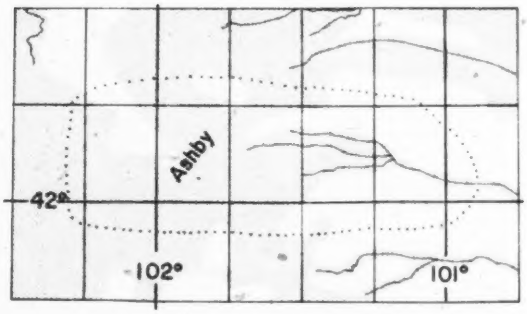

Figure 2. Map area for Sand Hills project. Hydrologic data absent in unshaded areas. Infiltration areas lie in the quadrangles inside dotted line.

Lake elevations are not the only points for contouring water table. Swamps, creeks, and flowing wells are also data. The flowing wells represent water table that is potentially above land surface but is hindered by a confining hardpan of silt and caliche. Where the flat depressions have no hydrologic features, the water table is probably only 10 feet below the surface. The elevation of a windmill is not the elevation of water table, nor is a tiny pond near a windmill; it is probably fed by the well. On the other hand, the elevation of a windmill is a quick guide to the elevation of the land surface; this saves hunting for topographic contours.

IT IS apparent that a 15-minute quadrangle is too small an area to yield much information. Given enough time, students could map water table for the entire Sand Hills, encompassing more than ten stream-gauging stations and infiltration areas. However, it is sufficient to study only a part of the Sand Hills, encompassing two adjacent stations and overlapping infiltration areas. These are centered in a set of twenty-one 15-minute quadrangles (Figure 2 and appendix).

Map projects usually start with confusion, and the first class meeting need accomplish no more than convince students that they can trace water-table contours on maps that have many lakes. In the second meeting, each student becomes acquainted with hydrologic features on the map assigned to him. He may start laying pieces of string along contours, using a 50-foot interval. The string can be displaced a mile or so laterally without seriously affecting the results. Maps with scant data (Figure 2) challenge the interested student. Maps with abundant lakes are easy to contour, and the success can motivate the student who has not shown interest. It helps to post an index map, with quadrangle names and student assignments, so that students can compare their work with contours on adjacent quadrangles.

By the third or fourth meeting, students should be ready to compile contours. Four maps at 1:250,000 (four miles to the inch) serve as base maps for the project. (See the appendix.) Although no marks should be made on the 15-minute quadrangles, the base maps are expendable; it is well worth providing two sets of base maps for each class section. On both sets, have a student carefully rule boundaries of the twenty-one 15-minute quadrangles; as guides, he will find black crosses on the base maps, where 15-minute lines intersect. On one set, quadrangle names are neatly written, and then the 21 quadrangles are cut out and distributed. Each student uses his portion of the base map for sketching contours, in pencil. He dashes lines where data are absent. He matches contours with those on adjacent quadrangles, and then compiles contours on the base map. After all the portions are compiled, the base maps are trimmed and taped together.

As the work progresses, the teacher monitors the work. Contours make a V pointing upstream at each stream crossing. The V may be faint except in the eastern part, where rivers cut as much as 100 feet below the upland; here, the V may extend ten miles or more westward, and contours may be bunched along the valley walls. The point of the V crosses the creek at the same topographic elevation as the contour; the 3,000-foot contour crosses at 3,000 feet. Conceptually, these contours demonstrate that ground water moves toward the creeks. In the western part, two or more contours close around the ground-water mound; this is obvious from elevations of the lakes there, but it is critical to the project.

Individual students are assigned special tasks. One is to plot the location of two stream-gauging stations:[3] Station 310 is in Sec. 8, T.24 N., R. 32 W., and its discharge averages 134 cfs (cubic feet per second). Station 7750 is in the SW 1/4 Sec. 17, T. 24 N., R. 31 W., and its discharge averages 199 cfs.

After contours have been compiled and stations located, another task is to sketch the limits of the infiltration area that feeds each station. Lines start at the station and are drawn upgradient, at right angles to each contour in turn; they join on the axis of the ground-water mound. The infiltration area lies somewhere inside the dotted line of Figure 2.

A third task is to measure the size of each infiltration area. This is done by tracing its limits through carbon paper onto a sheet of paper. Cut out the area and weigh it. To determine the unit weight of the paper, plot an area 20 miles square and weigh it. A balance with a precision of 0.1 grams will give results within 10 percent; a chemical balance will give more precise results.

Given the weights of the infiltration areas and the 400 square-mile area, each student calculates each area of infiltration. Given the discharge at each station, he calculates how many inches of recharge each year will equal yearly runoff past the station. This is just a matter of converting area in square miles to area in square feet, determining the number of seconds per year, solving for recharge in feet per year, and converting to inches. The numbers get large, and this is an opportunity to show students how to work with powers of ten.

IS this project feasible in junior high school? What are the hurdles? The $15 for maps, which might not get used, and the thought of devoting an entire week to a ground-water unit, should not be major obstacles. The biggest hurdle might be fear that the project will not work as neatly as described. Well, it may not. But the week should be considered an experiment in which there is nothing to lose. The primary goal is to gain experience in scientific inquiry, not to determine the exact infiltration rate. The teacher's role is to provide guidance, not answers.

Given this attitude, the teacher starts the ground-water unit with the map work. If students lose interest, the teacher stops the map work in midclass and starts on the textbook treatment of ground water; next meeting, the map work resumes. But so long as students show interest, map work continues; students will read the book outside of class in order to help their work on the maps. Even if time runs out before the project is completed, students will have learned much about the behavior of ground water. Incidentally, the teacher may find at the end of the week that class morale was never higher, and that he has discovered a new dimension to teaching. ☐

Appendix: Maps for Nebraska Sand Hills Project

Order from Distribution Section, U.S. Geological Survey, Federal Center, Denver, Colorado 80225. Allow one month for delivery.

Index to topographic maps of Nebraska. No charge.

15-minute topographic maps. Twenty-one maps at 50 cents: $10.50.

Ashby
Big Falls
Bingham
Bull Lake
Carr Lake
Dismal River Ranch
George Lake
Hire
Lakeside
Longfellow Lake
Mullen
Mumper
Seneca
Shimmins Lake
Spade Ranch
Spring Valley
Steverson Lake
Turpin Lake
Twin Lakes
Whitman
Wolf Lake

1:250,000-scale maps, Nebraska. Four maps at 75 cents: $3 per set. Order two sets per class section.

Alliance	NK 13-6
North Platte	NK 14-7
Scottsbluff	NK 13-9
Valentine	NK 14-4

20 percent discount for orders of $20 or more.

For ground-water atlas, geologic bedrock map, and Nebraska's water supply (no charge), write: Conservation and Survey Division, Director and State Geologist, University of Nebraska, Lincoln, Nebraska 68508.

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ROWBOAT OCEANOGRAPHY

Will Hon

MARE NOSTRUM

IT was bound to happen. We kept getting those questionnaires from educators asking about the kind of vessel we use for ocean study . . . and I kept writing in "JUNK." The other day a fellow with a Richard Halliburton glimmer came to check on our quaint oriental monstrosity. "Jehosaphat!" he chortled. "Junk it *is!* Just a pile of blooming junk. Does that piece of skiff really float?" "Usually," I said. "But if it sinks, we just wade ashore."

We don't apologize for the Carteret County Navy. Marine science is what you make it, and to us it is the study of the coastal environment in which we work and play. We are a people of, by, and for the sea; but, for most students the outer limit of contact with the ocean is out there where they paddle their surfboards to catch a wave. We have sent some advanced students out on the research vessels of our several local laboratories, and the career implications are considerable. Those experiences have the exhilaration of novelty and magnitude.

However, I would not swap ocean voyages for the homely field trips we take among the fiddler crabs and killifishes. In that statement there is logic of crunching significance. It relates to follow-up—what might be termed "addiction to a habitat."

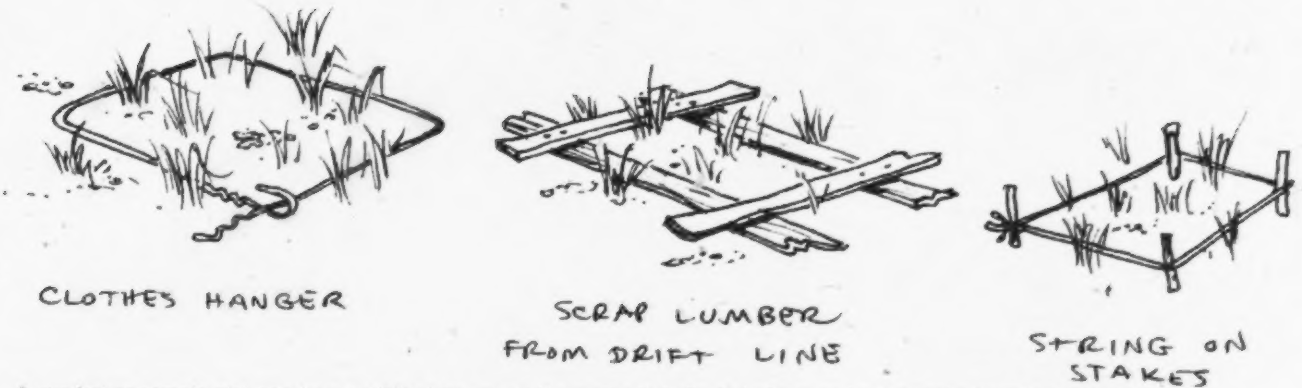
You see, the people of a coastal area wallow, at least visually, in a panorama of salt marshes, sounds, and dredging-spoil islands. These become the half-seen realities of a student's daily diet of views from school bus, car, and back porch. The result is growth of a strong subconscious rapport with the patterns and beauty of coastal vistas, along with conscious, bored acceptance of the too-common.

This is a perfect situation for an intellectual revolution. The edge of the sea, being the students' habitat, their parents' livelihood, and everybody's recreational outlet, is the crux of their attitudes. Teach them a fresh, questioning approach to marshes, and you have penetrated a daily routine. Give them a vision of life beneath the scintillating surface of the sound, and you have disquieted a casual acceptance. You probably stimulate a continuing dialogue between youngsters and the voices of the environment.

"Addiction to habitat" means that once you stir up more questions than answers, students can't pass a new drainage ditch or even an old spoil pile without rehashing the debate in search of better explanations. The mundane becomes mystical. Routine observations become clues for the environmental detective, who is happily hooked on the habit of applying ecology to life.

One nice thing about basing your program on a rowboat is that if the school board cuts your budget, you can do without the boat. You have the main items already: the environments and the students. Mix in any proportion, stir vigorously in the wind and sun for whatever time is available, and you have a unique concoction. Let

Mr. Hon is director of the Marine Science Project of the Carteret County Board of Education, Pivers Island, Beaufort, North Carolina.



A quadrat or sample plot can be established by any of the methods indicated above or just scratched out in the sand.

the students find or fabricate the equipment they need.

HOW do you help students tackle a complex environment with questions of transcendent impact? How do you help them arrive at the sensitive "I-thou relationship" with a slushy, stinking morass of black mud? Surely not by quoting to them a string of statistics in the professorial tradition. But a fair percentage of students will respond to the challenge of figuring out for themselves what makes a marsh tick.

"Tick" is not far-fetched, for ecosystem analysis is much like studying a watch. A lot can be learned by watching the movement closely. Still, some parts are hidden; you will want to remove parts one at a time to see how they relate to each other. When you remove one, though, it alters the whole functioning of the system. And a piece removed is no longer observable as part of a dynamic system—it is only an object. However, the looker can eventually picture the chain of events which make up the action of the system, and by analyzing several watches one may even be able to generalize some of the principles by which all timepieces function.

Likewise, you study an environment by observing the functioning, by examining individual pieces, and by questioning the role of parts individually and together. Basically you will ask:

1. What are the patterns?
2. What are the physical forces that create the patterns?
3. What happens to the patterns in time, as the forces vary because of cycles or disruption?

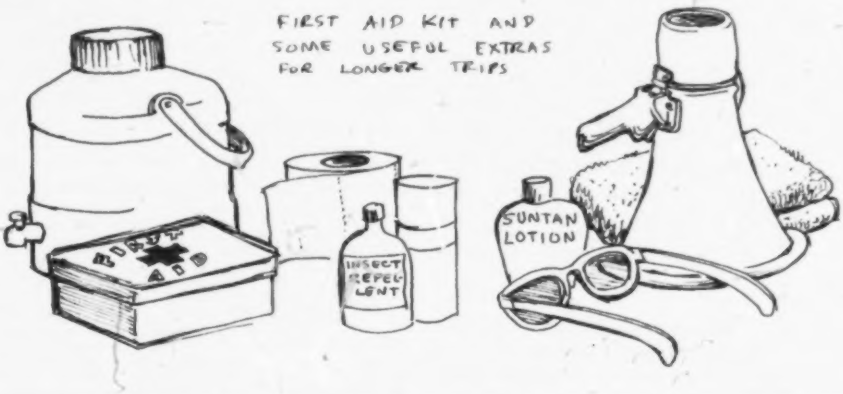
These three basic questions can be tackled in about that form, but will more often have to be molded to the specific environment.

IN a salt marsh, the first question may become these specific problems:

A. What are the relationships between plant distribution, tide, and elevation?
B. What causes the gradations in height and density of salt marsh cordgrass within the intertidal zone, and why do bare areas occur?
C. What are the habitats of the major animal species within the community, and what niches do they probably occupy? (This may lead to construction of a food web.)

These problems all call for systematic observation and recording. You, as teacher, can give the students the "benefit" of your experience and training in field ecology, resulting in fine data and only moderate student gains. Or you can let them evolve their own approaches and techniques, resulting in rather poor data but great student achievement. If you have the raw materials to work with, students will evolve a suitable method of data collection, almost always a sampling technique. Here are some typical solutions, suggesting the types of materials you should have on hand.

Sampling vegetation usually calls for a transect. This is a line, marked-off or imagined, which cuts across the area. This cross-section is described to represent the whole area. Several other transects will improve the accuracy of the description. However, even a transect is usually too much to describe in detail. More often time permits only sample plots along the


FIRST AID KIT AND SOME USEFUL EXTRAS FOR LONGER TRIPS

transect. A "quadrat" is such a sample, and practicality dictates the size. If you want percent of ground cover for each species or the number of stems of large plants, a square meter is reasonable for each quadrat. If you decide on a detailed analysis of small, diverse plant distributions or plan to clip and weigh the specimens, a one-fourth meter square is plenty.

The quadrat itself can be made of bent wire, boards, or a string marked in four equal lengths and stretched around four sticks. Tie one end of the string or tape to the first stick, push into the ground, and put another stick at the next mark. Push it in, and bend the string at a right angle. By the time you've done this twice more, the other end of the string is back at the starting point, and you have a square (more or less). The students may not even think of a quadrat frame, but may just scratch out a square (or circle) at each sampling station on the transect—time-consuming but valid.

The question that will arise later in the post mortem, if not during the sampling, is randomness, and it is a great question to debate. It touches on the fallacy of much of our daily observation and leads to enlightening discussions of such sampling techniques as Gallup polls and Nielsen ratings. In the field, it means not warping quadrat placement to fit preconceived notions. Uniform distances can be measured on the transect, or random samples can be taken by having a student throw a shell back over his shoulder and using that as the northeast corner of a quadrat. It can be done by marking off and numbering squares on a diagram of the area, then scrambling numbers on slips of paper, drawing them from a hat, and sampling only the corresponding squares of the marsh.

Out on the mudflat, snail distribution can be described by the use of quadrats. As the substrate (surface material) changes from sandy to muddier, a shift in snail species might be demonstrated by comparing samples. Aquatic samples can be taken from staked-off quadrats, but a more realistic approach is to seine a given distance and time in two habitats and compare. Repeat the studies as often as possible and average results.

Seines are variable in cost, but a hardware store minnow seine, complete with floats and leads (but not poles), is less than two dollars. It snags easily and won't last many trips, even with careful handling. Shovels and buckets will also be useful for sampling. Sieves are very handy, particularly if graded by mesh size. Stack them together, largest mesh on top. This might be ½" rabbit wire. to pick out large shells and twigs. Next, ¼" rabbit wire would get intermediate stuff. Then screen wire would allow only silt and sand to pass through. These permit instant sorting, when buckets of water are used to flush through a sample shovelful. For tiny aquatic organisms, a plankton net is the gimmick, and one can be fabricated from a woman's stocking and a jar lid ring. It is often assumed that the sampler must be towed behind a boat, but it can be tossed out from shore and drawn back to the student (several times) or tied to a piling so that the tide moves the water through the plankton net.

In all of these studies, elevations of sampling stations will be of obvious importance. The students doing a profile of the area will have more significant data if they work alongside the plant and animal samplers. The slick way to measure relative elevations is to have a surveyor's transit, but most students would have difficulty using it, even if you happened to have one. A carpenter's level will do, if you sight along the top of it. If it is too small, attach it to a straight board. If this isn't available, get a watch glass (shallow dish), fill it with water, and use it as the level on a board. Whatever the method of leveling, sight out to some point on a stake held by another student, mark the spot, and measure the height. If your sighting board was above the ground, measure its height and subtract that, of course.

An entirely different approach is to take a garden hose to the water's edge. Fill it with water, and have one person seal off each end. Go to the points to be compared in elevation and level the ends of the hose by watching the water. For distances longer than the hose, the process can be repeated up the face of a slope and the results added together.

THE second major question deals with the physical forces that create the observed patterns. Observation of these forces usually makes the observer wish for a recording instrument. These can be expensive, but you can subsubstitute homemade gadgets.

Of the factors observable on a shoreline, only a few are simple. A thermometer is usually obtainable to measure temperatures of air, soil, and water. Currents out in the water can be measured by weighted floats—lengths of wood with a lead sinker to hold them upright. Keep most of the surface of the float below water level (to minimize wind effect).

Turbidity of the water can be approximated by a Secchi disc, which is a weighted target that is watched as it sinks into the water on the end of a rope. The depth at which it disappears gives an estimate of cloudiness of the water relative to other sightings, but not an absolute measurement.

The rest are tougher. Even the common weather report statistics (relative humidity, barometric pressure, and wind velocity) are hard to come by. However, they aren't essential to ordinary field trips, and students on special projects can usually borrow a sling psychrometer, pressure gauge, and anemometer.

The measurement you will really want is salinity. Very accurate transducer instruments cost about $600. Even a simple spectroscopic device is half a hundred dollars. The simple answer is to use water density as an indicator of salts (which increase density). The instrument for this measurement is called a "hydrometer," and it costs $3 or more and is very perishable. If you have students who will prepare in advance, they can make a hydrometer (of much less accuracy). It is essentially a long tube with a float, balanced with a weight to make it stand up in the water. In tap water it would sink quite low, and the point thus determined on the tube represents zero parts per thousand (0‰). In pure ocean water, the hydrometer (or anything else) floats higher, and this point is about 35‰. Most estuarine water samples will fall somewhere between and can be estimated by comparison to the two known points.

Even with an accurate hydrometer, two tables of corrections are needed. The first allows for temperature (cold water is denser), and the second then converts density to parts per thousand.

Chemical analysis of seawater is tough, but would provide fascinating exercises for a chemistry class. The most commonly desired quality, after salinity, is oxygen content, which turns out to be a hard factor to pin down. Several companies now put out test kits which simplify water analysis, but they are not cheap. The oxygen content kits are based on the Winkler test, a multi-stage procedure. The other tests are only a little easier, and keeping reagents and glassware clean in the hands of students quickly leads to questionable results.

Pollution is an environmental parameter you would often like to measure. Notes on the obvious appearance and smell of soil and water samples may be the best you can do. The chemistry is complex. Pesticides perplex even the professional, and the breakdown products of pesticides in animal tissues are subjects to boggle the mind. For rowboat oceanography, pesticide study is past the frontier. However, it just may be that somewhere near you is the industrial chemist or public health biologist or marine researcher who can make it practical for you. Search him out.

THIS brings us to the third major category of questions suitable for analyzing environments. These questions deal with changes—with cycles, succession, and disruption. Coastal environments have special cyclic conditions which wax and wane with the tides. In addition to the daily cycle (semi-diurnal on our coast), there are monthly cycles and annual cycles. Tides vary in magnitude at various points along the coast according to the contour of the basin, and weather conditions often cause unpredicted changes in water levels.

Thus, local vagaries must be accounted for. Discuss these with local "experts," such as commercial fishermen. Do not believe anything sport fishermen tell you. They won't mean to deceive you, but often have difficulty pinpointing reality in their quest for Great Fishing Spots. Seriously, you can expect to hear some wierd "facts" from experienced outdoorsmen, so double-check your information.

The effects of civilization disrupt the normal cycles and rhythms of most environments these days. There is no point in ignoring them; it is far better if teachers grab opportunities to use disturbed habitats as ecological studies. Of course the specific problems will be different in each area, but some problems are discouragingly widespread.

- Spoil from dredging operations is dumped on marshes or sometimes even in shallow water. In the former case, marsh is destroyed, and rains later fan out silt to surrounding mudflats. In the latter case, currents quickly move silt great distances, sometimes killing oysters and scallops miles away.
- Pesticide pollution is obviously increasing. New restrictions on use of DDT don't eliminate it from the environment, much less affect the broad spectrum of other pesticides now in use.
- The recent flap about mercury is probably indicative of the many alarms we should expect as serious environmental monitoring becomes widespread. Unfortunately, fish kills, even spectacular ones, can seldom be definitely attributed to a certain effluent release. Of course, other things do cause fish kills, and *proof* of chemical kills is tough even in cases of *moral certainty*.
- Oil is a constant small problem and a serious major threat. The eastern United States, except Florida, has been lucky so far. For real catastrophe we don't even need a tanker running aground; there are many U-boat victims already offshore from World War II that could produce a real gusher.
- Sewage is a continuing problem of the seventies, particularly on the coast. Amazingly, many towns still dump raw sewage, and some cities still don't treat it well enough. Septic tanks in sandy areas can cause problems, and the many trailer parks, fish camps, and marinas of the coast add disease organisms and organic matter. Explore the effect called "eutrophication," in which overproduction of algae becomes more of a long-range problem than is direct poisoning of animal life.
- Drainage ditches have been sliced through thousands of acres of salt marsh in the name of public health. The question of mosquito control is still in doubt, but there is no doubt that ditches alter the ecology of a marsh. How and to what extent? No one is sure.
- The contours of our coast are constantly changed by land-moving. Draglines dig canals and build land with the material. Material from the sound is pumped to the beaches to create artificial dunes and berms. Grass is planted to stabilize and create dunes. Groins are built to stop erosion and enter into the picture of longshore transport. Inlets, channels, and harbors are kept open by constant manipulation.

There is obviously ample opportunity for students to find exciting problems of environmental tampering. In fact, it's difficult these days to find a place you can study without running head-on into such interference. Don't wear blinders—call a dragline a glorified spade, and study its impact on your area.

TO recapitulate how to use all this poor man's paraphernalia: Have it available so the students' imaginations won't be cramped, but don't cram it down their intellectual throats. After each trip, a full discussion of problems and approaches can develop alternate methods and materials. If the students wish, they can incorporate all or some of their ideas in the next field trip, along with the several techniques they will have discovered for themselves. In the end, you will have a sophisticated class which can approach an unknown environment and methodically dissect its ecology. ☐

CEDAR SWAMP ECOLOGY

Thomas J. Givnish and David J. J. Kinsman

LAST April, five undergraduates from Princeton University bumped along miles of rutted sand roads to arrive at Bear Swamp Hill Fire Tower. As we climbed this sentinel deep in the Pine Barrens of southern New Jersey, a sea of pitch pine green streamed from us to the limits of the horizon. Save for a cranberry bog visible far to the northeast, the landscape was pristine. The green spires of Atlantic White Cedar marched in columns along the waterways, snaking through the flat gray green of the pineland. All was quiet.

This year, we will not be climbing the tower. It is gone now, struck down by an errant plane. But the wilderness which stretched out beneath it still remains. Perhaps what we accomplished in the intervening months will help to protect it.

The Pine Barrens cover almost two thousand square miles of southern New Jersey. (Figure 1) They lie almost entirely above the Cohansey Formation, a geological unit of quartz sand and gravel with local clay lenses. The Cohansey is several hundred feet in thickness at the coast but wedges out westwards, the western limit coinciding closely with the western boundary of the Pine Barrens themselves. The sands and gravels are iron stained and contain local thin deposits of bog iron, which were exploited in the late seventeenth to early nineteenth centuries. Local pitch pine was used as the source of fuel, and shells from the nearby coast were used as flux. The iron industry collapsed, being unable to withstand the economic competition from the mountain ores of the Appalachians. A short-lived glass industry followed, exploiting the white quartz sands of the area, which form a surficial layer up to 1 to 2 feet in thickness. Today, lumbering and cranberry and blueberry growing are the main economic activities of the Pine Barrens.

Annual rainfall over the Pine Barrens averages 45 inches, of which close to half is lost by evapotranspiration. The very porous and permeable sands allow rapid infiltration of the precipitation down into the Cohansey aquifer, so that direct surface runoff into streams and rivers tends to be very low. In fact, the rivers are almost entirely fed by lateral and vertical leakage from the ground-water aquifer. In spite of the rather high annual rainfall, most of the Pine Barrens are arid much of the time. Ground surface and shallow subsurface levels tend to be rapidly drained of water; and the water table, except in swamps and along river courses, lies many feet below the surface. This situation greatly delays the biological breakdown of dead plant materials. Lack of humus and the general paucity of clay minerals result in the almost complete lack of soil development. The surface litter of dry leaves and branches makes ideal tinder and is periodically consumed by fire, which is a fairly frequent, natural, ecologically important phenomenon in the Pines.

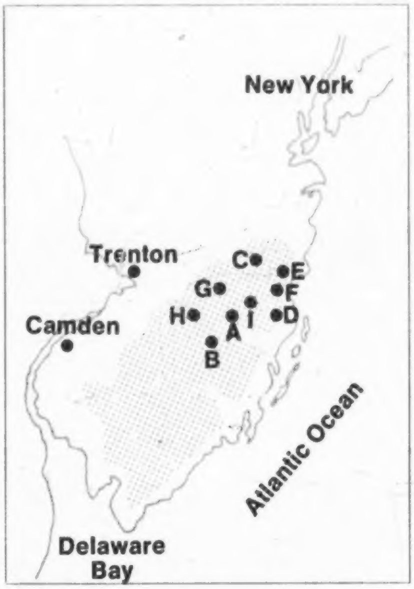


Figure 1. New Jersey Pine Barrens. The letters mark cedar swamp study sites.

In his *Hydrologic Analysis of the Pine Barrens Region,* Edward Rhodehamel of the United States Geological Survey estimates the total volume of water now held by the Cohansey to be 10.8 trillion gallons. Because the sands and gravels are relatively inert except for being sources of iron and silica, the ground water has much the same chemical composition as the rain from which it originates.

Rainfall over the Pine Barrens is extremely acid (pH about 4) owing to atmospheric pollution of the metropolitan east coast region, and river waters are also very acid (pH 4.5). The acidity of the river waters is also a reflection of the inert nature of the minerals of the Cohansey Formation. An additional source of acidity in these usually tea-brown river waters is organic acids derived largely from the swamps which line many of the river courses. The river waters are very soft and contain total dissolved solids concentrations of 15 to 25 parts per million.

The region surrounding the Pine Barrens wilderness is one of the most rapidly growing areas in the United States. All sectors of this spreading sprawl will need water for their future wants; all are eyeing the Pine Barrens as their potential supply.

Possible water exploitation schemes were examined by Rhodehamel in his 1970 USGS paper. The strategy he

Mr. Givnish is a student, and Dr. Kinsman is a professor in the Department of Geological and Geophysical Sciences at Princeton University, Princeton, New Jersey. This ecological study was carried out through a newly operative program of the National Science Foundation.

advocated was the construction of a network of wells along the lower reaches of the larger streams, well above tidal influence. Through pumping near the streams, recharge could be induced from the streams into the aquifer. Water would be caused to flow from the stream through its sand and gravel bed and toward the well bore below. This method promises to be the least disturbing to general ground-water levels, producing water by reducing the normal net loss from the aquifer.

One aspect of this plan that Rhodehamel, a professional hydrologist, failed to address, was the ecological effect this pumping would have on the Atlantic White Cedar swamps. These swamps line almost every Pine Barrens stream and are the habitat for many rare or endangered forms of animal and plant life. (Figures 2, 3, 4) The cedar trees typically grow in a peat deposit from 0.2 to 20 feet thick, which fills a portion of the shallowly incised stream valley. Soil moisture is abundant compared to that of the upland pine forests, and, consequently, late spring fires are generally discouraged from burning the otherwise flammable peat.

IN October 1970, a group of undergraduates at Princeton University submitted a proposal to the National Science Foundation through the NSF Student-Originated Studies in Environmental Problems Program (SOS) to study the effects of proposed water resource development upon local Atlantic White Cedar ecosystems.

The SOS program is a competitive program sponsored by the Foundation in order to encourage college students to express in productive ways their concern for the environment and to help support groups of students who can demonstrate their readiness to assume increased responsibility for their own educational development. Proposed projects must be student-originated, student-planned, and student-directed. The project must deal with a problem related to the physical, biological, and/or social environment. Furthermore, the approach to understanding the problem and the search for solutions must be interdisciplinary in nature.

Projects occupy 10 to 12 weeks during the summer, with all participants working full time on the project. While graduate students may participate, the emphasis has to be clearly on undergraduates. The students are directed by a student project director who organizes, manages, and writes up the study. A faculty member is designated as an advisor. While he should have expertise in the fields in question, his role is strictly passive. The students create their own educational experience.

Tom Givnish, then a sophomore majoring in mathematics, and co-author of the project proposal and this article, was the project director. David Kinsman, associate professor of geological and geophysical sciences at Princeton, co-author of this article and a geochemist now conducting his own study of processes controlling the chemistry of rain waters, river waters, and ground waters in the Pine Barrens region, served as the faculty advisor.

The 14-man project was organized from the start into four groups: biology, chemistry, geology, and land-use teams. A four-man steering committee, consisting of three team leaders and the project director, ensured that ample communication existed between the separate phases of the project and that the overall research program was modified as the project evolved.

Last spring, a preliminary survey team set out into the Pine Barrens to determine likely sites for investigation. The summer roles of the biology, chemistry, and geology teams would be to assess the impact, on cedar swamp plant distributions, of water removal by pumping from the sands underlying the swamp peats. Sites were examined to find a variety of water-table depths, salt gradients (in areas where salt intrusion had occurred), and light intensities. Swamps with different relief were searched out so that we could determine the importance of different horizontal flow rates within the peat layer itself. When we found ourselves at Bear Swamp Hill Tower, we had 20 potential sites, but we lacked three people for a 14-man team. NSF requests each project director to allow room in his group for students whose projects have failed to win financial support, so

Figure 2. A typical pine barrens landscape is dominated by pitch pine.

Figure 3. Rare double form of Rose Pogonia, an orchid common to the swamps.

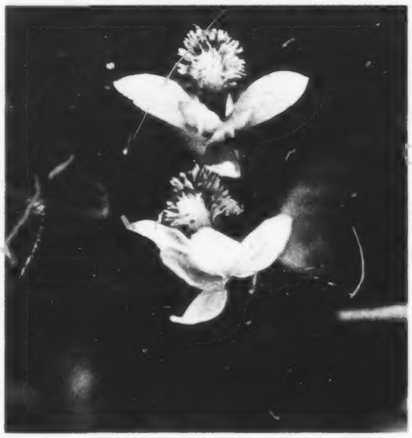
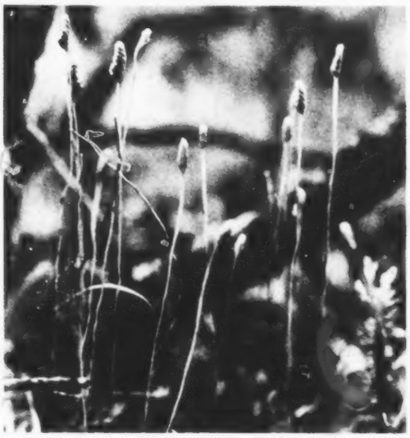


Figure 4. Curly grass fern occurs only in the Barrens and coastal Newfoundland.



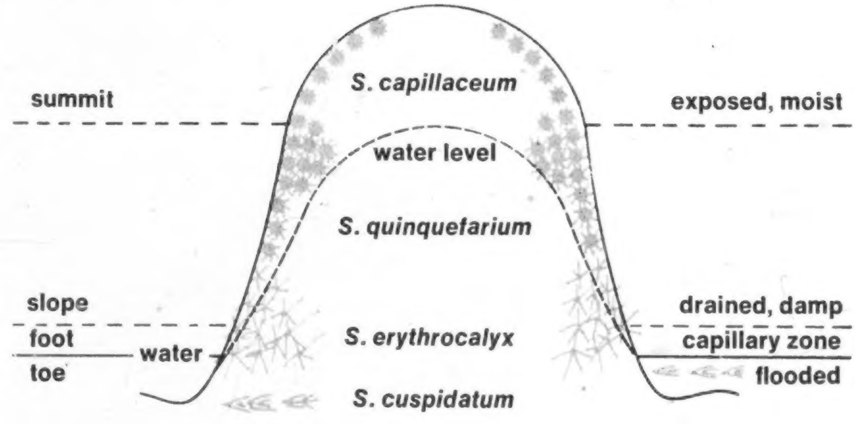


Figure 5. Schematic cross section of cedar swamp hummock. The sphagnum species zonation correlates with micro-environmental variations in moisture supply.

that they also can benefit from this unique research opportunity. Therefore, to fill the three places on the research team, students were chosen from the University of California at San Jose, Stanford University, and the University of Pennsylvania.

OUR first field problem was that of technique. We had originally intended to map plant distributions and measure light, water, chemical, and geophysical gradients over 200 × 300 ft swamp sectors at each of 14 sites. The geology team established the height and position of a rather random grid of points by plane table, probed for peat depth, sampled the peat with corers, and placed water-sampling wells in the peat layer. We measured the pH and temperature of water samples in the field and constructed maps for later use by the biology team. Under our original scheme the biology team was to identify and map all plant species at or above the taxonomic level of mosses, over what proved to be an unmanageable area.

The chemistry team remained at Princeton and analyzed the water samples collected by the geology team. Because of water coloration caused by tannic acid and iron complexes, ordinary colorimetric methods could not be used, and an atomic absorption spectrophotometer was employed in the analysis for sodium, potassium, calcium, magnesium, and iron. Chloride analyses were completed using a specific ion electrode. The chemistry team also blew the whistle promptly on the inordinate amount of sampling we had originally envisioned.

After initial difficulties, we adopted a simplified, more reasonable approach to our problem. The geology team surveyed two to four transect lines judiciously placed along light, water, chemical, or geophysical gradients at each site. The survey was conducted by transit, as opposed to the less accurate and more cumbersome method of alidade and plane table. Control stations were spaced approximately 30 feet apart, and the peat depth at each stake was measured.

When each transect had been surveyed, the geology team pulled a manila line taut through the line of stakes and tied a red marker every five feet on this line. Water-sampling wells were placed at a few of the stakes, and water-table depth was measured at all stakes on a line throughout the summer.

This initial groundwork by the geology team greatly speeded up and simplified the procedures of the biology team. Armed with 1 × 2 ft wooden or wire frames, team members counted plant individuals occurring within 2 sq ft sample areas spaced 5 ft apart adjacent to the red markers. Samples of moss and of most other unknown species were collected for later identification.

Plant banding on hummocks was another subject of study for the biology team. Hummocks are small convex mounds of sphagnum moss and peat which rise above the common floor of the swamp, generally surrounding a tree bole. Rising as much as 3 feet in a hemispherical dome above the swamp floor, hummocks have a greater evaporative surface-to-volume ratio than have flat or concave sections of the swamp. (Figure 5) Since chemical ions are concentrated in the interpore water as it evaporates from the capillary fringe, hummocks embody the sharpest, most sudden transitions in water level and chemical concentrations within the generally low relief of the swamp.

At Albertson Branch (site B; Figure 1), mosses, algae, and lichens formed a stratified zonation on hummocks and tree trunks that was traced as a function of water-table depth over 100 ft of transect. Along this transect, conditions of light intensity and ion concentrations were relatively constant. At another site, Atsion Lake (site H; figure 1), we found that four competing species of sphagnum moss had adapted themselves to living in environmental niches defined by water-table levels and other factors related to the geometry of the hummock. In the pools between hummocks, *S. cuspidatum* crowded out all competitors except algae. At the foot of the hummock, well within the capillary fringe, the large sphagnum, *S. erythrocalyx*, lined the pool edges. The sphagnum heads were growing with large spaces between them: Since evaporation loss is no threat to it, *S. erythrocalyx* was here maximizing its growth potential by increasing its effective light-gathering and gaseous-exchange surface. Atop these grew *S. quinquefarium* which showed a phenotypic response (locally adaptive growth response induced by the micro-environment) to increased evaporation loss. Near its lower border, with *S. erythrocalyx*, it also grew with a great deal of space separating each head, or capitulum. But with increasing elevation on the hummock, evaporation becomes a limiting factor, and the gaps between the heads grow smaller, until the moss is quite compact. Apparently *S. quinquefarium* was sacrificing growth potential to better compete in a less moist

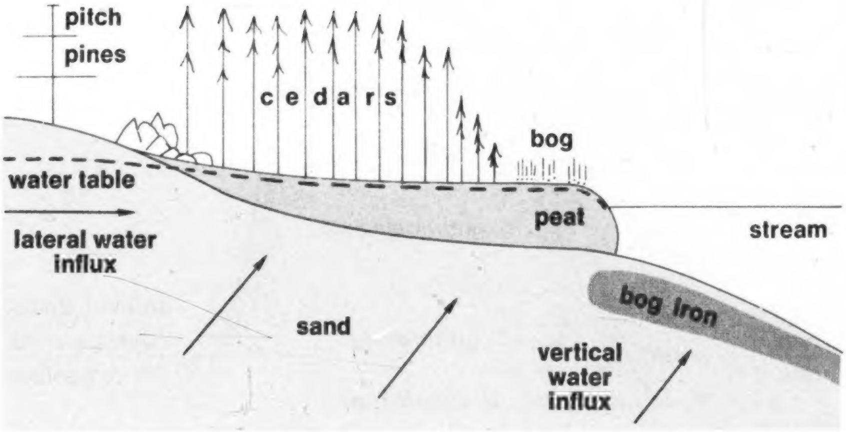


Figure 6. Schematic cross section and hydrology of a cedar swamp.

situation. *S. capillaceum* colonized the highest zone on the hummocks, occurring as a very compact form with very few gaps between the heads and seemingly adapted to the least moist situations.

A variety of sites was sampled. (Figure 1) Penn Swamp (A) was a young swamp with some hardwood still growing at its edges. Albertson Branch (B) had a strong gradient from high to low pH and from large to small fluctuations in water-table levels. Webbs Mill (C) was an open, highly acid sand bog with isolated islands of invading cedar. West Creek (D) and Forked River (E) were examples of salt-marsh cedar swamp interfaces with strong chemical gradients which were reflected in stable biological gradients. Oyster Creek (F), below the cooling water outlet of the nuclear power plant, had an unstable biological gradient which had been set up by a recent saltwater intrusion. Skit Branch (G) was a typical central Pine Barrens cedar swamp with a deep peat deposit and extensive bog iron formations. Atsion Lake (H) had a swamp on its edge with relatively uniform water levels year round due to the dam on the Lake, and Buck Run (I) was an open bog where cedar growth was impeded by excessive peat saturation and subsequent soil oxygen depletion.

UNDER many Pine Barrens streams, a layer of bog iron has formed. This reduces the effective permeability upward into the stream bed, and hence reduces base flow. The coefficient of permeability for well-decomposed peat varies widely, but published values are in the range 10^{-4} to 10^{-7} ft/sec; these values probably apply to the basal layers of peat. The upper peat layers probably have rather higher values of permeability. The coefficient of permeability is dependent upon the age and state of decomposition of the peat, its origin, and recent saturation history. In winter and spring, the fine-grained peat which underlies many of the swamps is flotated in the water which completely saturates the layer at this time. This causes the mean pore size to become much larger than it is when the layer had been dry or less moist.

Pressure from the hydraulic head in the sand below the swamp exerts itself all along the peat-sand interface. Rhodehamel states that the horizontal component of flow is perhaps only a tenth as large as the vertical component. We can see that there are three major water inputs to the swamp: (a) vertical migration upward through poorly permeable peat, (b) lateral flow through the upper more permeable layers of peat, and (c) precipitation. (Figure 6) The presence of relatively large concentrations of silica and iron in the peat waters indicates that (a) and (b) are major sources of interpore water in cedar swamp peats. The absence of swamps in areas lacking positive ground-water flow from below is in accord with this conclusion.

Cedar growth and metabolism are strongly affected by the amount of oxygen available to the roots. Because of the small flow rate for water in all but the most superficial layers of peat, oxygen is depleted almost completely below the water table by the metabolic activities of bacteria. Diffusion through air spaces toward wetter surfaces is the principal re-oxygenating process, but the slow rates of diffusion transport are far exceeded by the rates of bacterial oxygen use. Thus water levels control the dissolved oxygen gradient in partially saturated peat. Besides influencing cedar growth rate, this gradient is related to and largely controls soil decomposition of organic materials and the distribution of other bog and swamp plants. Generally, plants with root structures adapted for survival in saturated, oxygen-poor environments cannot compete with plants without these structures when both occur in an unsaturated, well-oxygenated environment. The metabolic load of these structures, together with a different soil ecology, combine to sharply reduce their original advantage.

Further, the level of the water table has immediate consequences thermally. Because it has a very high specific heat relative to that of the peat skeleton, water is of utmost importance to the annual thermal balance. The biogeographic distribution of cedar indicates that it does not root-freeze well; high water levels insulate the root systems. Second, a swamp or bog with high water table will have fewer late frosts and cooler summer soil temperatures than will areas with deeper water tables. The recharge of swamp peats by ground water from below will also moderate seasonal temperature extremes. As many plants reach their northern or southern extremes of distribution in the Pine Barrens, these factors are of great importance, not only to cedar distribution, but to the overall ecology of the swamps.

The peat bed which occupies the larger portion of stream valleys lowers the permeability of the valley floor, and thus acts to conserve hydraulic head, to smooth out sharp changes due to precipitation, and to keep the flow of the stream relatively constant over time. Increasing swamp age and associated decrease in the peat permeability tend to increase these desirable factors.

Finally, high water levels protect against swamp fires. Cedar is thin barked and killed by all but the least intense of ground fires. It does not stem sprout, as does the pitch pine. The Pine Barrens flora and fauna have evolved within a fire-ecology; if the water levels were permanently lowered in the swamps, fires would burn through them, killing the dominant cedar vegetation and affecting the overall ecology of the Pine Barrens.

The Plains are a natural example of an area lacking linear firebreaks of swamp peat. They comprise 20,000 acres, straddling several contiguous watershed divides. These areas are characterized by pigmy pitch pines, 2 to 5 feet tall, with a low age distribution, reflecting the high frequency of burnovers. If, following ground-water withdrawal, the natural swamp peat firebreaks became ineffective, the vegetation of the Pine Barrens as a whole would probably come to resemble that of the Plains.

We can categorize the probable effects of induced recharge pumping as follows:

1. Water would be lost from the swamp peat through its bottom layer into the unsaturated sand in the cone of depression at a rate of 0.05 to 3 ft/day.
2. Since the cedar roots reach far into the peat, cedar evapotranspiration would continue at only a slightly reduced rate until there was almost no water-saturated peat within the cedar root zone.
3. Late spring frosts and high summer soil temperatures would occur, and over winter freezing would be deep without positive ground-water flow into the peat.
4. Burnover rate and burn probability would increase markedly as layers of potential ground fuel develop in the dry moss and litter (from the dehydrated peat).
5. Thickness of the peat layer would be reduced by increased peat decomposition and structural compaction.
6. Dissolved oxygen would increase sharply in the soil, causing long-term succession from open water saturated sphagnum bogs, to cedar swamps with their better drained peats.
7. Long-term succession would occur from cedar swamp to heath or pitch pine lowland communities, with their well-drained and thoroughly decomposed humus layer.

In the light of these findings we have recommended the following:

1. The pumping schedule should be cyclic, not continuous, with a period of 1 to 4 days, depending upon the local characteristics of the swamp peat.
2. A full-scale pumping experiment should be conducted on some small watershed in the Pine Barrens, preferrably over a 5 to 10 year period. The setup period would consist of monitoring the swamps ecologically by our methods, gathering data on evapotranspiration, and on natural groundwater flow rates. The remainder of the project would consist of the actual carrying out of a pumping schedule, with a monitoring of the swamps during the test period, to assess the exact results of the program.
3. Owing to the vulnerability of the ground-water-table aquifer to pollution from above, the control of all sewage effluent release is extremely critical. Municipalities and counties should provide much more legal protection for the aquifer than they presently do.

IT SEEMS to us that in studying cedar swamps in relation to schemes of ground-water withdrawal, we have used a few tactics basic to assessing similar environmental problems. We could have attacked the ecological effects of water resource development on the Pine Barrens as a whole. However, the scope of that problem is staggering. By asking what would be the changes caused in cedar swamp plant distribution by induced recharge pumping in riparian zones, we delimited clearly our investigation. Then, we analyzed what we considered to be the significant controlling factors. Natural situations are impinged on by a multitude of variables, most of which we probably fail to perceive. We cannot list all possible factors. By investigating the more obvious limiting variables, such as the local hydrologic, thermal, and chemical budgets, we began to understand what was happening and the processes involved.

We next constructed a simplified model of the complex natural environment, considering only a few variables, such as water-table levels and chemical concentrations. When certain conclusions we drew from our initial model did not agree with our observations, we included other variables, such as oxygen depletion or peat permeability. In this way we slowly approached a more complete understanding of the workings of the complex natural environment.

Finally, we made predictions concerning the probable course of events if the present water withdrawal plan were carried out. Since man is an ever-present and tangible part of the environment, we pointed out the social consequences of our studies. Whether or not these predictions are true is a matter for further research; as data from situations similar to those we have studied become available, we can finally assess the assumptions and scientific analysis we made. ☐

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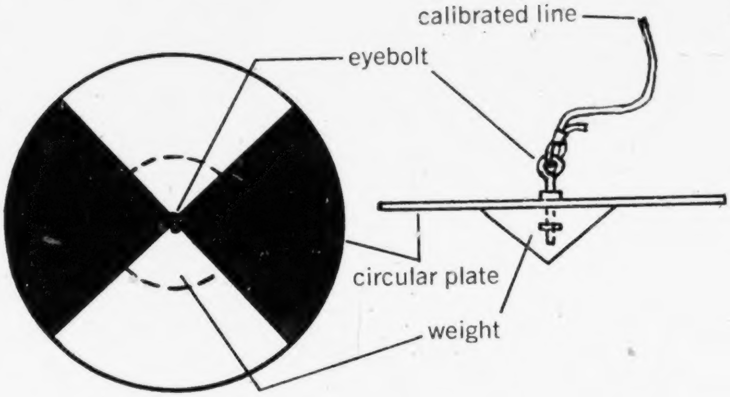
EARTH SCIENCE

The Secchi Disk: An Instrument for Measuring Water Transparency

THOMAS P. EVANS, Assistant Professor, Department of Science Education, Oregon State University, Corvallis



Top and side views of the Secchi disk, used for determining water transparency. The disk is made of a metal plate, which may be 20 to 30 cm in diameter.

Water transparency, expressed as the depth or limit of visibility, is of interest in the study of lakes, ponds, rivers, or estuaries because of its relationship to the transmission of light in water. Water transparency is determined primarily by dissolved substances, suspended materials, organisms, and the angle and intensity of entering light. [2] These same factors determine light transmission in water and, consequently, regulate biological processes within bodies of water. Therefore, a comprehensive study of a lake, pond, river, or estuary would be incomplete without consideration being given to the transparency of water.

One of the most widely used instruments for measuring water transparency is the Secchi disk, devised by Professor Secchi, an Italian. The Secchi disk does not provide an actual measure of light transmission, but once the limit of visibility is determined, estimates of light transmission can be derived. The limit of visibility is approximately the region of transmission of 5 percent sunlight. [2] Biologists interested in primary production often use three times the limit of visibility to estimate the lower limit of the euphotic zone; i.e., the vertical range of transmission of light effective in photosynthesis. [1]

The Secchi disk (see the Figure) consists of a circular metal plate, 20 cm in diameter, attached to a weight by means of a small eyebolt. After cutting out a circular plate, drill a hole in the center slightly larger than the shank of the eyebolt. Paint the lower surface of the plate black to eliminate reflection of light from that surface. Use masking tape to divide the upper surface into four quadrants. Paint two quadrants directly opposite each other white and the intervening ones black.

The weight is constructed by supporting a three-inch metal funnel upright with a ring and ring stand. Plug the tube of the funnel with asbestos or glass fibers. Screw one or two nuts onto the lower end of the eyebolt. Use a burette clamp to suspend the eyebolt into the center of the funnel so that the "eye" and approximately one-fourth inch of threads are above the top edge of the funnel. Be sure that the funnel and ring stand have good support because the next step is to fill the funnel with molten lead. When the lead cools, remove it from the funnel and paint it black. Screw the eyebolt out of the weight. The nuts remain in the lead and facilitate assembling and disassembling the Secchi disk.

Assemble the Secchi disk by screwing a nut up near the "eye" of the eyebolt, inserting the shank of the eyebolt through the metal plate and screwing the eyebolt into the weight until the plate is held firmly in place. Attach a calibrated line or chain to the eyebolt. An advantage of this method of construction is that the same circular plate can be used with interchangeable weights. Larger weights are often necessary to hold the Secchi disk in position in moving water.

To use the disk, lower it into a body of water on a calibrated line until it disappears from view. Take a line reading. The circular plate must remain horizontal to the surface at all times. Raise the disk until it reappears, and note the two readings. The limit of visibility is the arithmetical mean of the depth at which the disk disappears and the depth at which it reappears.

Variables, such as time of day, different observers, distance of observer's eye from surface, degree of roughness of water, diameter of disk, condition of disk's upper surface, and clearness of the atmosphere, cause the Secchi readings to vary for the same water on the same date. [3] In order to obtain data that are consistent, accurate, and useful for making comparisons, observe the following practical suggestions:

1. Do not allow the upper surface of the disk to become dull or scored.
2. In rough water, use a water telescope or the protected side of a boat or dock. A water telescope is simply a four-sided wooden box with a glass bottom. Place the glass bottom just below the surface and view from above.
3. Be certain that the line or chain is accurately calibrated and that the diameter of the disk is known and constant.
4. View the disk vertically with observer's eye at a fixed distance from surface. One meter is a suitable distance.
5. Make the observation in the shade, during the middle of the day; avoid early morning and late afternoon observations. A large umbrella makes an excellent sunshade.
6. In addition to the Secchi readings, keep complete records of the variables, including date, time, place,

observer, and description of the atmosphere.

The Secchi disk, used as directed, provides a useful tool for studying the environment. Following are some of the questions that can be investigated.

1. To what extent does water transparency differ for the same body of water from day to day and season to season?
2. What are the differences in water transparency of local lakes, ponds, rivers, or estuaries?
3. Does water transparency vary significantly with distance from industrial or sewage treatment plants?
4. Do temperature, dissolved oxygen, phosphates, pH, number and kinds of living organisms, and salinity differ significantly at various Secchi depths? (Suggestions for collecting water samples at various depths were presented by Evans in the May 1969 issue of *The Science Teacher*.)
5. What specific factors can be identified that are reducing water transparency of local lakes, ponds, rivers, and estuaries?

Another investigation relates to the disk itself. A review of the literature reveals that the Secchi disk is described as being from 20 to 30 cm in diameter. This lack of agreement leads to the following question. What variations in readings are introduced by using Secchi disks of different diameters for a wide range of water transparencies? Such an investigation might lead to the standardization of Secchi disk diameters. [1] □

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BIOLOGY

Comparison Test for Oxygen Content of Water Samples

DAVID J. KUHN, Assistant Professor, Biology Department, Mankato State College, Mankato, Minnesota

Biological education for the Seventies will surely see an increasing emphasis on education in the environmental sciences. The desirability and necessity for these programs is indisputable; the lack is in appropriate teaching materials. The following simple qualitative test for oxygen would be broadly applicable in environmental education at the precollege level.

The basic chemical substance used in these experiments is an alkaline solution of sodium pyrogallate, an oxygen absorber which is used in classic experiments requiring an oxygen-depleted atmosphere. For example, seeds can be suspended over an alkaline pyrogallate solution to illustrate the fact that seeds require oxygen for germination. [1]

A simple qualitative test for oxygen content of various bodies of water can be performed as follows: Completely fill a 50 cc capacity test tube with a sample of water. (A slightly larger capacity test tube may also be used.) Using tweezers, drop three tablets of potassium hydroxide (KOH) into the solution. **Warning:** Do not handle KOH with the fingers. It is caustic to the skin and should be handled with care. Also, close the KOH bottle promptly, or the residual pellets will freeze together. Make a "cup" out of a glass tube 2.5 cm (1 inch) by .6 cm (¼ inch) diameter by heating one end of the tube until the ends fuse. Place solid sodium pyrogallate in the tube; press the pyrogallate with a glass rod to pack it firmly. Cover the exposed surface with a small amount of water from the sample solution.

Drop the "cup" in the test tube. Place a rubber stopper into the end of the tube. Be certain that the tube is filled to the brim to minimize air spaces that will affect the validity of the results. Repeatedly invert and reinvert the tube.

The liquid will develop a brownish tint; an intermediate purple may appear momentarily, but disregard this. The intensity of the brownish tint will vary with the oxygen content; a deeper color is an indication of a greater amount of oxygen.

The test can be used as a simple qualitative test for the oxygen content of various readily obtainable water samples, such as tap water, distilled water, rainwater, or aquarium water. A simple experiment might compare the oxygen content of "normal" tap water with boiled tap water and water that has been aerated.

This oxygen-content comparison technique is useful in pollution studies of almost any type. In the classroom, the oxygen content of water in a polluted aquarium containing a considerable amount of decaying organic material can be compared with that in a well-maintained, "balanced" aquarium. These studies can be carried on for several weeks; the oxygen-content data can be compared with changes in the living systems in the aquarium. Charts and graphs can be prepared. These data can be projected from microecosystems to environmental disturbances in larger aquatic ecosystems. These activities reinforce the principles learned in the classroom experimentation and make them more relevant to students' life situations. Excellent films, such as the "Who Killed Lake Erie?" [1] clippings and scientifically accurate articles from magazines of popular interest can also be effective in increasing the awareness and understandings of students of the factors that affect environmental quality.

This simple oxygen comparison technique can also be used effectively in field situations. The minimal amount of apparatus and materials required make the procedure appropriate for use in field trips. A portable "field kit" with sufficient quantities for an entire class can be quickly and easily prepared. The oxygen content of the water at various "stations" along a stream, or above and below a major source of pollution, may be tested. The oxygen content of the water can be tested and related to the life forms present at each location.

The test can be made more quantitative by the use of colorimetric methods; i.e., a color reaction of the water-pyrogallate mixture may be compared with a color chart of known concentrations of oxygen expressed in parts per million. The oxygen content of a water sample may be determined using the Winkler Method [2, 3] or by using an electronic oxygen probe. The color of the resultant reaction in the tube could be compared to the chart and the approximate O_2 content of the sample determined. If a spectrophotometer is available, it also may be used to compare samples of known oxygen content with various unknown solutions.

This crude technique for oxygen content comparison of various bodies of water, if used in the proper context and at an appropriate level of sophistication, can be an invaluable teaching aid. ☐

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[1] *Who Killed Lake Erie?* NBC Educational Enterprises, 30 Rockefeller Plaza, New York, N.Y. 10020.

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GENERAL

Water Sampling Apparatus and Determination of Dissolved Oxygen in Water

THOMAS P. EVANS, Assistant Professor, Department of Science Education, Oregon State University, Corvallis

A study of a pond or lake would be incomplete without investigating the quantity of dissolved oxygen (DO) in the water. The presence and success of various aquatic organisms are dependent upon the quantity of available oxygen. In some cases, oxygen is the limiting factor as far as survival of organisms is concerned. This is true in urban areas where large quantities of organic waste drain or are dumped into ponds, lakes, and rivers. In fact, the lack of available oxygen in water is one of the major problems of mankind. The quantity of DO is so important that its study seems highly appropriate for science students.

This article describes an apparatus for collecting water samples and a procedure for determining the quantity of DO in water. Included in this procedure are a list of reagents and directions for their preparation. In addition, various investigations utilizing the apparatus and procedures are presented. These investigations are suitable for science teachers and students and should serve as focal points for individual and group research projects.

Water Sampling Apparatus

The collection of water samples from various depths requires some ingenuity. However, the apparatus illustrated in Figure 1 may prove to be useful. The exact dimensions are not given because they are not critical. In fact, teachers and students are encouraged to improvise and to improve the apparatus.

Little explanation is needed for constructing or operating the apparatus. Primarily, it consists of a can which is attached to an aluminum rod. A large cork is held in place by an expansion spring. The cork and spring are secured by a long bolt. After the can is immersed to the desired depth, the spring is released by pulling the wire attached to the cork. Once opened, the can fills with water, and the spring forces the cork into place. Marks are placed on the aluminum rod to indicate the various depths. The rubber hose is convenient for transferring water into sampling bottles, and it reduces the water's contact with atmospheric oxygen.

Determining DO in Water

A number of methods are available for determining the DO content of fresh and salt water. [1] The method described here is the Winkler method. [1,2] The reagents and directions for their preparation follow:

1. Manganous sulfate solution ($MnSO_4 \cdot H_2O$): 364 grams in 1 liter of distilled water.
2. Concentrated sulfuric acid (H_2SO_4).
3. Alkaline-iodide reagent: 700 grams potassium hydroxide (KOH) and 150 grams potassium iodide (KI) in 1 liter of distilled water.
4. Starch solution: 1 percent solution of soluble starch in a 20 percent solution of sodium chloride (NaCl). Bring the salt solution to a boil before adding starch.
5. 0.1 normal sodium thiosulfate stock solution ($Na_2S_2O_3 \cdot 5H_2O$): 25 grams in 1 liter of distilled water. The solution may be preserved by adding 0.4 grams sodium hydroxide.
6. 0.01 normal sodium thiosulfate titrating solution: dilute 100 milliliters of the stock solution to 1 liter with distilled water. This solution should be standardized using 3 drops of starch solution and 10 ml of 0.01 normal potassium bi-iodate ($KIO_3 \cdot HIO_3$). To prepare 0.01 normal iodate solution, dry a small quantity of reagent grade potassium bi-iodate at 105°C for one hour. Cool and weigh out 0.325 grams of potassium bi-iodate. Dissolve the iodate in 200 ml of distilled water and transfer to a 1 liter measuring flask. Dilute with distilled water to the measuring mark. If potassium bi-iodate is not available, a 0.01 normal solution of potassium dichromate ($K_2Cr_2O_7$)

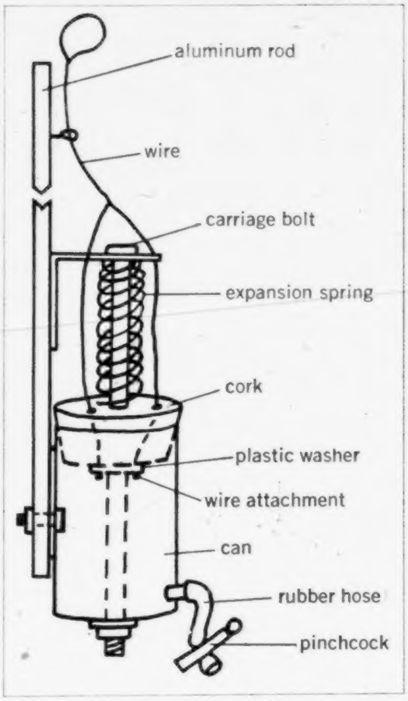

Figure 1. The water sampling apparatus.

may be used to standardize the thiosulfate. It is prepared in a similar manner except 0.490 grams of potassium dichromate are used.

Using the apparatus, collect a sample of water at the desired depth. Transfer the sample into 250 ml sample bottles, extending the rubber hose to the bottom of each bottle. Allow the bottles to overflow two or three times their volume and replace the stoppers so that air is not entrained.

Because oxygen may be lost due to an increase in temperature and/or microbiological respiration, the DO should be determined within one hour after the sample is collected. If this is not possible, add the manganous sulfate and alkaline-iodide solutions to the water samples in the manner described in the following paragraph. Once treated, the samples may be set aside and analyzed at a later date.

To each sample, add 2 ml of manganous sulfate solution followed by 2 ml alkaline-iodide well below the surface of the liquid. Replace the stopper and mix by inverting the bottle several times. The following reactions are involved.

$$Mn^{++} + 2(OH) \rightarrow Mn(OH)_2$$
$$2Mn(OH)_2 + O_2 \rightarrow 2MnO(OH)_2$$

When the precipitate settles, remove the stopper and add 2 ml of sulfuric acid. Restopper and mix by gentle inversion until solution is complete. Iodine, equivalent to the original DO content, is liberated. The following reactions occur.

$$Mn(OH)_2 + 2H^+ \rightarrow MN^{++} + 2H_2O$$
$$MnO(OH)_2 + 4H^+ + 2I \rightarrow Mn^{++} + I_2 + 3H_2O$$

Pipet a 50 ml aliquot from each sample and place in separate, wide-mouth Erlenmeyer flasks. Titrate with 0.01 normal thiosulfate to a pale straw color. Add 2 ml of starch solution and continue the titration until the blue color disappears. The titration reaction follows:

$$I_2 + 2Na_2S_2O_3 \rightarrow 2NaI + Na_2S_4O_6$$

Calculation of the DO in parts per million is accomplished by substituting into the following formula.

$$\frac{1000}{A} \times B \times F = X$$

A is the milliliters of aliquot used. B is the milliliters of thiosulfate used in the titration of iodine. F is the milligrams of oxygen equivalent to 1 milliliter of standard thiosulfate.

The oxygen equivalent (F) is computed from the standardization of thiosulfate (see reagent number 6). Divide 10 by the number of milliliters of thiosulfate required to make the standardization and multiply the results by 0.08. This calculation is based on one gram atom of iodine being equivalent to eight grams of oxygen.

Possible Investigations

Once the apparatus has been built and procedures for the determination of DO in water are well in mind, a number of questions might be investigated. Included are the following:

1. Are there major differences in the DO level of local lakes, ponds, streams, and rivers?
2. Does the DO differ from depth to depth, season to season?
3. Are there noticeable relationships between animal and plant life and the amount of DO in the water?
4. Does the DO level in water vary significantly with distance from an industrial plant?

Hopefully, teachers and pupils will not confine themselves to the suggested investigations. They are encouraged to identify and investigate other problems which are of real concern to mankind. Such activities might help to bridge the schism that currently exists between the science classroom and the rest of life.

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ECOLOGY

Phosphate—Some Studies of How It Affects Our Water

ANN L. ABELES, Assistant Professor, Science Department, Frederick Community College, Frederick, Maryland

This classroom project consists of three activities concerning the presence of phosphate in water. If you can obtain one of the commercially available kits for testing water for phosphate ion,[1] you may wish to use the following activities in grades 5-12. You will need to help the younger students with some of the background material and vocabulary and with some of the techniques, such as pipetting liquids and using a microscope. Further study of the water microorganisms is intended for secondary school students. These activities are designed to give students an idea of how phosphate ion in water is measured and how much phosphate is present in detergents and fertilizers, to demonstrate that soil effectively binds phosphate, and to have students observe the changes in the microscopic life in pond or stream water when the water is polluted with excess phosphate.

The third activity in this series can lead into or follow a study of how to use a microscope, what sorts of microscopic life are likely to be found in a pond or stream, and how to identify and "key" these microorganisms. Because it is likely that you will find a large variety of organisms in the pond or stream water, you should have some references with pictures of algae and protozoans available for the students.

The people of the world are realizing that our precious supplies of fresh water, our streams and lakes, are rapidly being polluted. What the average person notices is that more water is being covered by ugly, smelly algal growths, that fish are dying, and that streams and lakes are filling with sediment. The heavy growth of algae and the accompanying changes in the body of water are called eutrophication. This process occurs because we are filling our waters with waste materials which are rich in nutrients that algae need for growth. The algae then grow and multiply tremendously, taking up the nutrients such as nitrogen and phosphorus from sewage.

This bloom of algae blocks out sunlight to the lower layers of water. When the algae die, they are decomposed by bacteria which use up the oxygen in the water. The fish then die from lack of oxygen; their decomposing bodies release more nutrients; more algae and bacteria grow; and soon the whole body of water is a boggy, smelly mess. The body of water fills up with the decaying mass of organisms and the silt from runoff from the neighboring land.

Some of these processes occur normally all the time. However, man has upset the normal rate of aging in bodies of water with the huge amounts of nutrient-containing sewage he puts into the water every day. This increased amount of material speeds the eutrophication and death of our lakes and streams.

One of the nutrients thought to be important in this increased eutrophication is the phosphate ion. In normal, clean water this nutrient is present in a few parts per billion (ppb). [4] This means that normally there would be only a few grams of phosphate in one billion parts, or 1,000,000,000 milliliters of water. However, the sewage waters of our cities contain hundreds to thousands of times that much phosphate. Consequently, if you measure the phosphate content of a river just below a sewage treatment plant, you will often find 10 to 30 ppm (grams per 1,000,000 ml water) phosphate. [4] An unnecessary amount of this is probably coming from the detergents we use.

A few years ago detergents were in the news because they were not degradable by organisms in the water and were building up to such concentrations that the rivers were covered with foam. Indeed, foaming water came out of the faucets in some communities. Now detergents are "biodegradable," which means they can be broken down by microorganisms. But this is where the problem occurs again. The degraded detergent, specifically the phosphate in the detergent, is one of the nutrients blamed for the increased eutrophication. Some cities have banned phosphate in detergents. Unfortunately, no good substitute for phosphate has been found. Although phosphate-free detergents would not stop the eutrophication, they would be a good start.

Another potential source of phosphate is the fertilizers used by farmers. The use of fertilizer has grown tremendously in the past 20 years. For instance, the amounts of nitrogen and phosphorus contained in all fertilizers sold in the United States were, respectively, 1.0 and 0.85 million tons in 1949-50; 2.8 and 1.2 million tons in 1959-60; and 6.8 and 1.9 million tons in 1968-69. [3] The amount of phosphorus used has more than doubled in the past 20 years and is increasing steadily. Although large quantities of fertilizers are used every year, this phosphate is very quickly bound up by the soil in forms that are difficult to remove. Even phosphate which is washed off the fields into ponds or rivers is quickly bound up by soil particles that are also being washed into the water. Although some of the phosphate may later be released to organisms in the water, recent studies by ARS scientists H. Kunishi and R. Terkeltoub indicate that the runoff of fertilizer phosphate is probably not one of the major sources of the phosphate in our waters. [5, 6]

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[1] Sources for phosphate test kits: LaMotte Chemical Products Company, Chestertown, Maryland 21620, or Hach Chemical Company, P.O. Box 907, Ames, Iowa 50010.

Another important agricultural source of phosphate is in the sewage and runoff from livestock feedlots and poultry producers. Agricultural Research Service (ARS) scientists are experimenting with plant-soil filters and better designed sewage lagoons as methods of controlling this waste. [2] Municipal sewage is also a major source of phosphate in our waters. A plant-soil filter project is being tested in a pilot plant near Phoenix, Arizona. These plant-soil filters consist of large grass-covered basins. The grass uses up the nutrient materials in the water. The water then percolates down through the soil for further treatment. [1]

The activities which follow are designed to teach a method for measuring the amount of phosphate in detergents and fertilizers. These experiments measure the ppm phosphate (PO_4^{-3}) in water. Often the phosphate is measured as ppm phosphorus (P); 1 ppm phosphate is approximately equal to 0.33 ppm phosphorus. Using this method one can show that soil can bind phosphate and remove it from water. After adding a known amount of phosphate to some pond or stream water, one can observe the changes which occur in the microscopic life in the water.

Measuring the Phosphate Content of Fertilizer and Detergent Using a Water-Testing Kit

Materials

1 phosphate test kit (LaMotte or Hach) which will measure 10 to 50 ppm phosphate
500 ml distilled water
One 100-ml graduated cylinder
A few grams of fertilizer or detergent
Two 150-ml beakers
2 stirring rods
1 balance capable of weighing to tenths of a gram
1 marking pencil or labels
One 1-ml pipette
Two 100-ml volumetric flasks

Method

1. Dissolve 1 gram of detergent or fertilizer in 100 ml distilled water or dissolve in a volumetric flask and dilute to 100 ml with distilled water. Label this "first dilution."
2. Pipette 1 ml of the first dilution into another volumetric flask and dilute to 100 ml with distilled water, or put the 1 ml in one of the beakers and add 99 ml of distilled water. Label this "second dilution."
3. Follow the directions for phosphate analysis included with the kit. (If the solution is too concentrated, dilute the second dilution 1 to 10. If the solution is too weak, try measuring the phosphate concentration of the first dilution or a 1 to 10 dilution of the first dilution. Adjust calculations for these other dilutions.) The analysis will give the ppm phosphate in the second dilution.
4. Calculate the concentration of phosphate in the first dilution and in the detergent or fertilizer as follows:
   a. Since the second dilution was made by diluting the first 1 to 100, the concentration of phosphate in the first dilution is 100 times what you measured with the kit. For example, if you measured the second dilution to be 25 ppm phosphate, the first dilution would be 100 times 25, or 2,500 ppm.
   b. The first dilution was made by dissolving 1 gram of detergent or fertilizer in 100 ml of water, so again the concentration of phosphate in the fertilizer or detergent is 100 times larger than the concentration of the first dilution. In the example, the concentration of phosphate in the material would be 100 times 2,500, or 250,000 ppm. This is the same as 250,000 grams phosphate in 1,000,000 grams detergent, or 0.25 grams phosphate in 1 gram of detergent or fertilizer.
5. If you have time and enough testing materials, determine the phosphate content of other detergents and fertilizers.

Optional Calculations

1. After you have calculated the grams phosphate per gram of fertilizer, calculate how much phosphate you are adding to the soil when you follow the directions for diluting the fertilizer for potting soil.
2. Weigh out the amount of detergent which is recommended for washing a load of clothes. Calculate how much phosphate is present in that amount of detergent (one or one and one-half cups or whatever is recommended on the label).

Using Soil to Absorb Phosphate

Materials

300 to 500 g dry subsoil
One 100-ml graduated cylinder
Two 300-ml beakers or 2 pint jars
One 1-ml pipette
1 g detergent or fertilizer
Two 150-ml beakers
1 balance for weighing soil and fertilizer
One 10-ml pipette
Materials and method for measuring phosphate
$CaCl_2$ (calcium chloride)
Distilled water (at least 1 liter)

Procedure

1. Weigh 150 g of the dry subsoil and put it into one of the 300-ml beakers or jars.
2. Repeat with another 150 grams from the same soil sample, and place in the other 300-ml beaker or jar.
3. Pour 100 ml of distilled water into the first beaker or jar with soil. Shake and stir well. Label "clean water."
4. Prepare a dilute solution of detergent or fertilizer using the following procedure:
   a. Dissolve 1 g of the fertilizer or detergent in 100 ml distilled water in a 150-ml beaker.

b. Pipette 1 ml of this solution into the other 150-ml beaker and add 99 ml distilled water. Mix well.

c. Pour 50 ml of this solution into the other container of soil. Add 50 ml of distilled water, mix well, and label "phosphate water."

5. If you are using a test kit, analyze some of the remaining 50 ml of solution for phosphate. The concentration of phosphate which you added to the soil will be one-half of that which you measure with the kit since you diluted it with some distilled water. For example: If the concentration of phosphate in the remaining solution is 25 ppm, the concentration of phosphate in the solution you added to the soil will be 12.5 ppm. Since there was a total volume of 100 ml or 0.1 liter (after you added the water) and since 12.5 ppm is the same as 12.5 mg/liter, it follows that you have added 1.25 mg phosphate to the soil. (You added 1/10 of a liter.)
6. Set the containers of soil and water or solution aside to settle. This should take one or two days. If the soil doesn't settle out, you may add $CaCl_2$ to help precipitate the particles. Add no more than 0.11 grams of solid $CaCl_2$.
7. When the water or solution above the soil is relatively clear, carefully pipette out 10 ml of the solution and analyze for phosphate. There should be very little phosphate in the sample which had no added phosphate. The amount remaining in the other solution will depend upon the type of soil which you used.

Questions

1. Did your soil sample release a measurable amount of phosphate into the clean water?
2. Did you find a measurable amount of phosphate in the solution of detergent or fertilizer which had been mixed with the soil and allowed to stand a few days? Can you explain this?

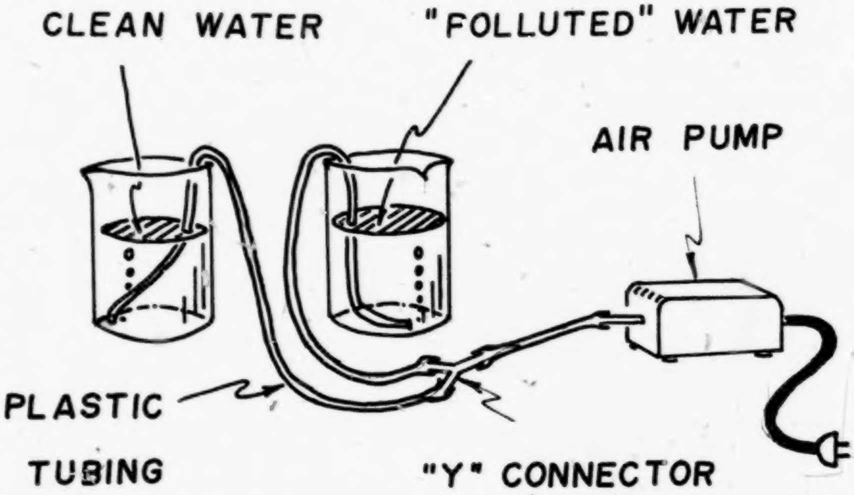
Changing the Balance of Microscopic Life in a Water Sample with Added Phosphate from Detergent

Materials

1 liter pond, river, lake, or aquarium water (will be called "pond water")
Two 600-ml beakers
1 aquarium pump (or continuous source of compressed air)
1 "Y" connector for the tubing
1 screw-type tubing clamp
6 to 8 feet of clear plastic tubing which will fit the pump or compressed air and the Y connector
1 g detergent
One 100-ml graduated cylinder
One 150-ml beaker
1 microscope with 200 to 600 magnification
Microscope slides and coverglasses (depression slides are very good)
1 medicine dropper
One 1-ml pipette
One 5-ml pipette
Materials and method of phosphate analysis

Procedure

1. Dissolve 1 g of the detergent in 100 ml distilled water and proceed as in the first activity to make dilutions and measure the concentration of phosphate in the detergent (unless you know the concentration from the previous activities).
2. Put 500 ml of the pond water into each of the large beakers. Make sure the water is well mixed before you divide it.
3. Pipette 5 ml of the solution containing 1 g detergent in 100 ml water into one of the beakers of pond water. Label the beaker.
4. Remove enough water from each of the beakers of pond water to analyze them for phosphate. The concentration of the phosphate in the "polluted" water should be around 10 to 30 ppm.
5. Cut a 1-ft length of the clear tubing, and use it to connect the air pump to the Y. Put the screw clamp on the tubing. Cut the remaining long piece of tubing in half, and attach the pieces to the other arms of the Y.
6. Bring the beakers of water, tubing, and pump over to a good source of light, such as a window or large fluorescent desk light.
7. Position the whole assembly so that you can run the free ends of the tubing into each beaker. Turn on the air pump and adjust the airflow by means of the screw clamp (on the 1-ft piece of tubing) so that a good supply of air bubbles through both beakers of water but does not disturb the water too violently (see the Figure).
8. Place one or two drops of water from each beaker onto separate slides. Cover the drops with a



What are the effects on microscopic life when pond water is "polluted" with detergent?

coverglass and examine the water for microorganisms. If you wish, you may make some counts of the number and kinds visible in the average viewing field. There should be very few.

9. Let the beakers sit with the air bubbling through for several days. Make a microscopic examination of the water in both beakers each day and record any changes. Usually there will be a "bloom" of microorganisms, algae, after about three days.
10. Each day you should add a little clean, not chlorinated, water in order to maintain the same volume in each beaker. Do not add more than about 20 ml each day. If there is too much evaporation, cover the beakers loosely with plastic wrap.

Questions

1. Was there a change in the number and/or kinds of microorganisms in the "polluted" water?
2. How would you prove that it was due to the phosphate?
3. What would happen if you used a solution of fertilizer instead of detergent?
4. Do you think the results would have been different if you had put some soil in the bottom of the beakers?
5. Were there changes in the number and kinds of microorganisms in the pond water without added phosphate? Why?

Additional Activities

1. Measure the phosphate content of streams or ponds nearby.
2. Try different kinds and concentrations of fertilizers and detergents in these three activities.

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ECOLOGY

Environmental Activities and Problem Solving

THOMAS R. BREHMAN, Earth Science/Biology Teacher, Maine Township High School North, Des Plaines, Illinois, and MUSA QUTUB, President, The Illinois Association of Colleges and Universities for the Improvement of Earth Science Teaching, and Assistant Professor of Earth Science, Northeastern Illinois State College, Chicago, Illinois

Can we explain away the man-created tragedies of the environment in terms of failure on the part of educational processes to convey the requisite information about "Nature" to students? We don't think so. A reflection on one's own educational background should reveal a wealth of knowledge, both physically and biologically oriented, to refute such an explanation. This being the case, why does man persist in his headlong plunge into environmental oblivion? Perhaps it is not what information of environmental import is conveyed but rather how the material is made available to students that will make it effective.

We all learn of wind patterns and climatic regions, in geography; of the importance of sunlight to plants and of plants to animals, in science; of the destruction of the eastern forests by the early settlers, in history; and of the need for sufficient clean air and water, in health. This is the very crux of the problem: All these vital concepts and many more are conveyed to students through educational "isolation" instead of through correlation of the material in an intelligent and comprehensive overview.

We live on a dynamic planet; an understanding of the processes that shape and reshape our environment can be attained only through a broadly based study of the natural setting. If we are to survive the ravages of pollution, students must see interrelationships and be challenged to provide solutions to problems affecting the quality of the natural environment.

Using Landform Models

Even within a particular subject area one can introduce a multidisciplinary approach. Such an approach was devised and tested by the authors with tenth-grade students in a biology course where landform models proved the means to link geography, meteorology, biology, and earth science. It is obviously impossible for field trips to be conducted to all significant physiographic areas of the world. Using landform models, available from several commercial scientific supply companies, brings these regions into the classroom at a fraction of the cost of actual visitation and no loss of time in transit. The results were most gratifying.

Landform models also make useful teaching aids for environmental studies because: (a) they are three-dimensional representations—students have no difficulty in visualizing various landscapes; (b) they are realistic in being distinctly colored—visual appeal is stronger than is true of aerial photographs; and (c) they can depict major physiographic regions.

The teacher, or the students, can devise "potential pollution" situations for any of the landforms. The opportunities for developing such problems are nearly endless, since a model can depict a variety of topographic, hydrologic, and agrobiologic phenomena. Possible solutions can then be proposed by correlating the models with reference materials, and with geographic and topographic maps of similar regions. For example, a topographic quadrangle map of Bright Angel, Arizona, presents the reality of topographic features depicted on a "canyon" model. An individual class report describing the inherent difficulties encountered in the proposed Colorado River dam project would here be an appropriate interdisciplinary investigation. A corollary to this could entail an oral report on the ecological disruption precipitated by construction of the Aswan High Dam in Egypt. A comparison of the two projects should be most enlightening. Having the class view the Sierra Club's film "Grand Canyon" would also augment this aspect of environmental studies. Similar treatment can be given to other landform models, corresponding maps, films, etc. The problems and difficulties of ecologically sane farming, mining, road construction, and waste disposal, as well as the distribution of population centers as related to local "relief" and water supply should be continually reinforced throughout the investigations. Although landform models are designed to represent different physiographic regions, the principles involved in the ecologically rational management and utilization of the resources in each region are quite similar.

An extension of these investigations in environmental science makes use of a world map, colored pins, and a cork-back bulletin board. Thus, while involved in environmental problem solving, the class can conduct an "Earth Watch" by scanning newspapers for articles reporting ecological disasters throughout the world. Color-coded pins for oil slicks, air pollution, radioactive waste disposal, detergents, topsoil erosion, and the like can identify geographic areas undergoing such abuses. This type of class activity graphically illustrates the concept of "Whole Earth" integration. If there is adequate space surrounding the map, students can post the news articles and connect them with string to their respective locations.

This kind of approach does not stress "correct" answers; students are encouraged to offer a variety of possible solutions to the environmental problems with which they are faced. The depth to which students analyze each situation will be commensurate with both grade level and individual ability and interest. The keynote to all investigations and activities is critical thinking nonetheless.

Inasmuch as the method employed is flexible, the teacher can devise a number of alternative procedures to be carried out over whatever time is available.

Environmental investigations and activities are appropriate at any level of education as long as the environmental factors are centralized. Quite obviously, much further exploration of alternative methods of involving and encouraging students to develop an intelligent and active interest in environmental preservation is necessary. The field is wide open for imaginative suggestions.

Books and Materials

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The following films are of correlative value in environmental investigations. Information concerning any of the films can be obtained by writing: Sierra Club Films, c/o Associated Films, Inc., 25358 Cypress Avenue, Hayward, California 94544.

Grand Canyon, 26 minutes, sound and color.
Two Yosemites, 10 minutes, sound and color.
Wasted Woods, 15 minutes, sound and color.
An Island In Time: The Point Reyes Peninsula, 28 minutes, sound and color.
Glen Canyon, 29 minutes, sound and color.
Nature Next Door, 28 minutes, sound and color.

The following topographic maps depict regions in the United States representative of the landform models.

Baraboo, Wisconsin
Bright Angel, Arizona
Grand Teton, Wyoming
Ironton, Missouri
Mt. Rainer, Washington
Orbisonica, Pennsylvania
Point Reyes, California
Potreor Cortado, Texas

Topographic maps depicting areas east of the Mississippi River can be ordered from: Distribution Section, U.S. Geological Survey, 1200 South Eads Street, Arlington, Virginia 22202. Maps of areas west of the Mississippi River can be ordered from Distribution Section, U.S. Geological Survey, Federal Center, Denver, Colorado 80225. ☐

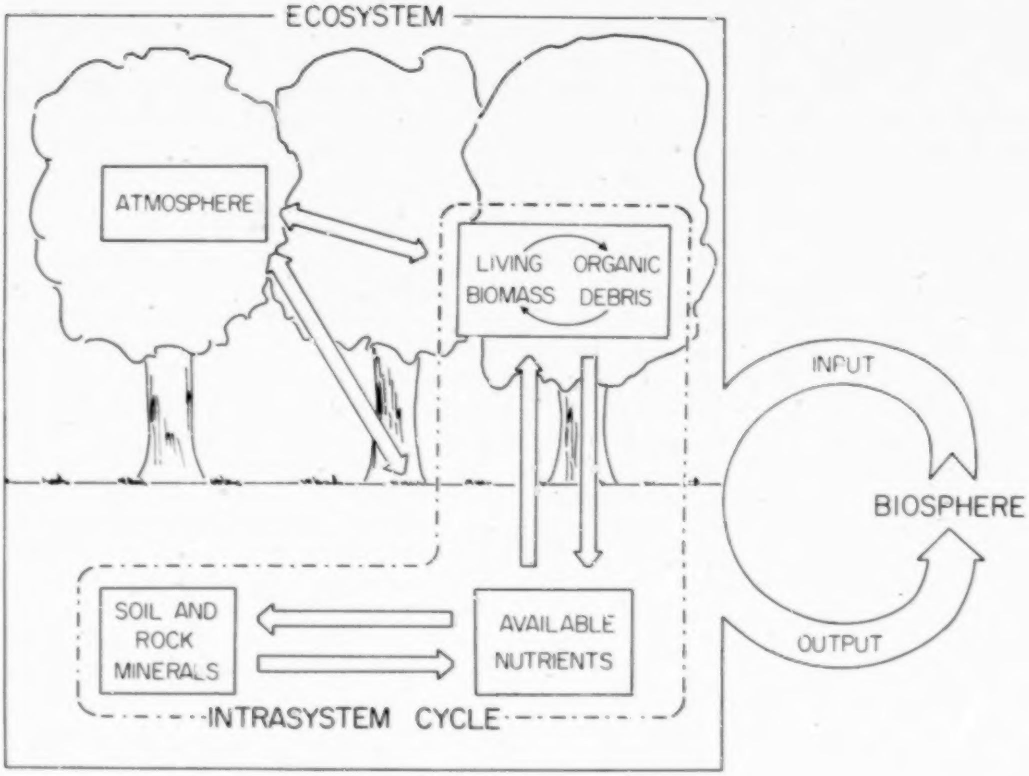
ECOSYSTEM
ATMOSPHERE
LIVING BIOMASS
ORGANIC DEBRIS
INPUT
BIOSPHERE
OUTPUT
SOIL AND ROCK MINERALS
AVAILABLE NUTRIENTS
INTRASYSTEM CYCLE

Figure 1. Simplified nutrient relationships for a terrestrial ecosystem, showing sites of accumulation and major pathways. Inputs and outputs link individual ecosystems with the rest of the biosphere.

BIOGEOCHEMICAL CYCLES

Gene E. Likens and F. Herbert Bormann

PROFESSOR Eugene Odum has referred to ecological systems as the "functional units of nature." Although this definition is oversimplified and general, it has appeal in our attempts to piece together the complex components of the biosphere. An ecosystem may be simply defined as any unit of nature in which there is a functional and dependent interchange of energy and nutrients between living and nonliving components. An ecosystem may be very small, such as a puddle; or it may be large, such as a forest or an ocean. It also may have precise or real boundaries, such as those of a lake or an island, but more frequently it doesn't. Ecosystem boundaries on land are often rationalized and established by the investigator to facilitate conceptualization and study.

Dr. Likens is an associate professor in the Division of Biological Sciences at Cornell University, Ithaca, New York, and Dr. Bormann is a professor of forest ecology, School of Forestry, Yale University, New Haven, Connecticut.

Ecosystems are the building blocks or functioning units that make up the biosphere.

The survival of ecological systems depends upon a continuous input of energy and nutrients. An ecological system is richly endowed with a budget of inputs and outputs, and one of the reasons why it is difficult to assess the impact of human activity on nature is the lack of precise information about these inputs and outputs and about the delicate adjustments that maintain a balance. We should also remember that since all ecosystems interact, changes in one may cause changes in others by a kind of chain reaction. Projects such as the logging of a forest or the building of an interstate highway may have consequences far beyond the individual project. Similarly, technological solutions frequently do not solve environmental problems; rather, the problems are often merely shifted from one level to another or from one ecosystem to another. There are a great many examples of this; two should make the point.

Air pollution in Great Britain and in the Ruhr Valley has been greatly alleviated by a very simple technological change. Taller smokestacks and chimneys push the smoke and gases higher into the atmosphere. However, this so-called "cure" has merely shifted the problem to somebody else. Wind carries the smog from these industrial areas primarily to Scandinavia. Here the increased addition of sulfur compounds, mainly sulfur dioxide and hydrogen sulfide, in the atmosphere has led to a striking increase in the acidity of rainfall. Since 1956 the acidity of rainwater has increased more than 200 times. This in turn has led to the acidification of lakes and streams in Scandinavia—to the extent that reduced growth and even kills of salmon and trout have been observed. There have also been effects on the soil (loss of fertility), on forestry (reduced growth), and corrosion of buildings and other structures. It is estimated that damage from acid corrosion in Sweden alone may amount to as much as 1 percent of its gross national product. This is analogous to chemical warfare, and the Swedes are not particularly happy about it, as you can imagine. What with fishing recently banned in more than 50 of their southern lakes because of mercury pollution and with DDT concentrations in Baltic fish now 10 times higher than in fish from the North Sea, the Swedes have rapidly become aware of the biospheric complexity of environmental problems.

It is frequently stated that through technology we may be able to dump our solid trash into the ocean with a minimum of ecological disturbance. One current plan calls for grinding all trash and garbage from the Baltimore and Washington metropolitan area, making a slurry of it, and then transporting it by pipeline to the edge of the Continental Shelf, some one hundred miles offshore. Here again, the problem is merely shifted from trash on land to trash in the ocean. And it is clear that there are far too few data to support the claim that this is really a solution to the problem.

Recently we heard an interesting suggestion for the trash problem. It was that we continue to collect solid trash and garbage from individuals and organizations. After it is collected, it could be compressed, sterilized, wrapped in a waterproof container, and then given back to the individual. He could do anything he wanted with it: put it in his attic, in his garage, basement, or warehouse—just as long as he didn't remove it from his property. Obviously this solution has immediate appeal in that it puts the problem where it belongs, with the individual or the industry who generates the waste, but also obviously it is unworkable. For one thing, like so many proposals, it penalizes urbanites.

These examples clearly point out our vital need to reuse and recycle material much in the same way that natural ecosystems do and to make our decisions on the basis of an honest accounting in which all costs are included. After all, this is a basic ecologic principle in the functioning of natural ecosystems. There is a distinct lack of good ecological information upon which to prejudge the effects of proposed technological developments and manipulations. Sound, quantitative information is needed to assess environmental problems from a holistic view and to develop honest balance sheets.

LET US look more closely at one of the basic functions of an ecosystem, the flow of nutrients and other materials. First we must distinguish between flux and cycling. Flux refers to the directional input and output that occurs across ecosystem boundaries. From such information we can determine budgets and observe balancing mechanisms. Cycling refers to the two-way exchange between living and nonliving components within the ecosystem, but is tempered by external flux. Within the boundaries of an ecosystem, chemicals are continually withdrawn from the abiotic reservoir of the ecosystem (e.g., the air, the water, or the land), utilized by and circulated through the biotic portion, and returned in one form or another to the abiotic reservoir.

Because chemicals cycle between living and nonliving components, the terms "biogeochemical cycling" or "nutrient cycling" are frequently used to describe this process or basic ecosystem function. The term "mineral cycling" has been used widely, but strictly speaking, minerals do not cycle within ecosystems. Also it should be apparent that the movement of water and air is vital to the transport of chemicals such as N, C, H, O, P, S, etc., between and within ecosystems.

There are few quantitative data available for the flow and cycling of these materials in natural ecosystems. There is a large amount of data on various aspects, but it is exceedingly difficult to assemble this information in terms of an entire ecosystem and all of its interacting parts.

We began studies about eight years ago to determine the magnitude of the natural biogeochemical flux and cycling of nutrients for a forest ecosystem in New Hampshire. Like a city, the forest ecosystem survives because of a specific and continuous input and output of nutrients, and we wanted to quantify these fluxes as well as the rates of internal recycling. Our ecosystem unit is

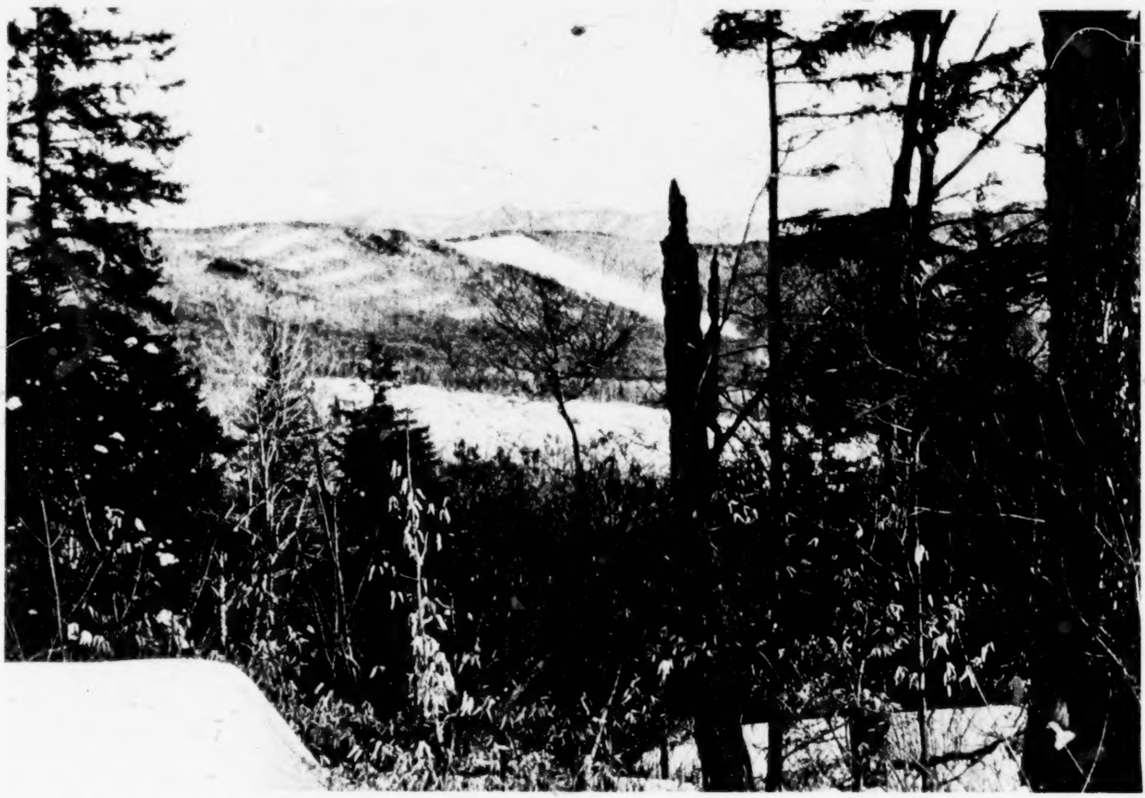

Figure 2. Watershed experiments in the Hubbard Brook Experimental Forest. In the foreground is the commercially logged watershed No. 101. The horizontal clear cut strips are on W4, and the V-shaped clearing in the center background is W2. Peaks of the Presidential Range of the White Mountains are in the background. (This photo was taken in January 1971.)

a watershed or drainage area. Therefore, its boundaries are defined by the drainage of water.

Our studies have been done in cooperation with the U.S. Forest Service within the Hubbard Brook Experimental Forest in West Thornton, New Hampshire. Several students and colleagues from various universities and federal laboratories also are involved in the overall project.

THE FOREST is characterized by beech, yellow birch, and sugar maple trees. The bedrock is granitic and is watertight. This latter point is exceedingly important for these quantitative studies. If water were lost through deep rock strata rather than through the drainage stream, it would be almost impossible to know how much water was lost in that way and also what amount of nutrients that water carried out of the system. Since our ecosystem is watertight, all of the liquid water leaving the system is measured at gauging wiers. Water vapor is lost by evaporation and transpiration.

Precipitation collection stations scattered throughout the forest provide data on the input of both rain and snow throughout the year. By and large the monthly input of precipitation is constant throughout the year. However, loss of water by stream flow varies enormously. The largest runoff occurs in the spring when the heavy accumulation of snow melts. Approximately 57 percent of the total yearly runoff occurs in the months of March, April, and May. In contrast very small amounts of water are lost by stream drainage during the summer months when most of the water evaporates directly to the atmosphere from the forest vegetation. Yearly, about 123 cm of water come into the ecosystem in precipitation; 58 percent runs off in streams, and 42 percent is lost by evaporation and transpiration.

Precipitation chemistry is highly variable. First of all, we found that precipitation is surprisingly acid. The average pH of rain and snow is about 4, and hydrogen and sulfate ions are the dominant ions. Also, significant amounts of nitrate, ammonium, calcium, magnesium, phosphate, chloride, sodium, and potassium fall onto the ecosystem in rain and snow. Exceedingly clear, pure mountain streams drain these forested watershed-ecosystems. The major ions in stream water are calcium and sulfate, but in relatively low concentrations. (Table 1)

To determine the magnitude of nutrient flux across the ecosystem boun-

Table 1. Weighted average concentrations of various dissolved substances in bulk precipitation and stream water for undisturbed watersheds 1 through 6 of the Hubbard Brook Experimental Forest during 1963-1969.

CHEMICAL	PRECIPITATION	STREAM WATER
	mg/l	*mg/l*
Calcium	0.21	1.58
Magnesium	0.06	0.39
Potassium	0.09	0.23
Sodium	0.12	0.92
Aluminum	[a]	0.24
Ammonium	0.22	0.05
Hydrogen	0.07	0.01
Sulfate	3.1	6.4
Nitrate	1.31	1.14
Chloride	0.42	0.64
Bicarbonate	[a]	1.9[b]
Dissolved silica	[a]	4.61

[a] Not determined, but very low

[b] Watershed 4 only

daries, we measured the concentration of chemicals in both the precipitation and the stream water. These data multiplied by accurate data for precipitation and stream runoff, provided by the Forest Service, allow us to calculate budgets of nutrient inputs and outputs. We have made measurements of this sort on six watershed-ecosystems of the Hubbard Brook Experimental Forest since 1963. (Table 2) Normally there are net losses of calcium, magnesium, aluminum, sodium, and silica from the ecosystem via streams each year. However, losses of chloride and potassium in stream water about equal the inputs in precipitation. The net loss of sulfate, although usually consistent, is small in relation to the amount input in precipitation. Of particular interest is the finding that more nitrogen and phosphorus are brought into these undisturbed ecosystems, dissolved in rain and snow, than are lost in drainage waters. Thus, generally small amounts of nutrients are lost from these undisturbed forested ecosystems in drainage waters relative to the amounts input, stored, or cycled.

Man's activities can completely reverse these relationships. It was apparent from the beginning of our study that the opportunity to study experimentally some of man's effects on an entire ecosystem was exciting, scientifically sound, and a most powerful approach to unraveling the complexity of ecosystems.

OUR first experiment of this type was deforestation of an entire watershed (see Figure 2). In the autumn of 1965 every tree and shrub on the watershed was cut and reduced to ground level. No roads were built, and none of the logs were taken out of the system since this wasn't a typical logging operation. Later the system was treated with herbicides to inhibit all regrowth of vegetation. The ecosystem was maintained in this condition until 1969 when herbicide treatment was stopped, and the forest was allowed to regrow.

As a result of this experimental deforestation the runoff of water increased 40 percent the first year, 28 percent the second year, and 26 percent the third year. This means that the increased runoff loss would amount to a quantity of water about 35 cm deep over the entire watershed during the first year. Most of this water would have been lost by transpiration had the vegetation not been cut or killed. In summer, when the runoff is normally low, the increase in stream discharge was orders of magnitude greater per unit area than on adjacent uncut areas.

However, chemical concentrations in stream water increased unexpectedly. (Figure 3) In particular, nitrate concentrations increased spectacularly, reaching a maximum concentration of almost 90 mg per liter. Normally concentrations are less than 2 ppm in the undisturbed watersheds. These increased concentrations plus the increased discharge of water had a very great effect on the nutrient budgets. (Table 3) Typically there is a relatively small net loss of calcium from the undisturbed forest (8 to 10 kg/ha-yr in 1966-69). In contrast 75 kg/ha were lost from the deforested watershed the first year and 90 kg/ha the second. For potassium, the same relationship was observed although the change was even larger.

The change in the nitrate-nitrogen budget was very large. Normally nitrogen compounds are conserved by these mature forest ecosystems. In other words, more is added in precipitation with rain and snow than is lost from the system in drainage water; there is an annual net gain for the system. In contrast, the deforested system lost 97 kg/ha the first year and 142 kg/ha

Table 2. Average chemical input and output for undisturbed, forested watershed ecosystems 1 through 6 of the Hubbard Brook Experimental Forest during 1963-69. Output data for W2 after treatment are not included.

CHEMICAL	NO. OF WATERSHED YEARS [a]	MEAN VALUES (kg/ha-yr)			
		INPUT	OUTPUT	NET LOSS	NET GAIN
SiO_2-Si	10	[b]	16.4	−16.4	
Ca	30-32	2.6	11.7	− 9.1	
SO_4-S	10-15	12.7	16.2	− 3.5	
Na	30-32	1.5	6.8	− 5.3	
Mg	30-32	0.7	2.8	− 2.1	
Al	10	[b]	1.8	− 1.8	
K	30-32	1.1	1.7	− 0.6	
NO_3-N	10-15	3.7	2.0		+1.7
NH_4-N	10-15	2.1	0.3		+1.8
Cl	8-12	5.2	4.9		+0.3
P	2	0.02 [d]	0.01		+0.01
HCO_3-C	4 [c]	[b]	2.9	− 2.9	

[a] No. of watersheds times years of data
[b] Not measured, but very small
[c] Watershed No. 4 only
[d] Estimated concentration of 2 μg/liter

Table 3. Comparative net losses or gains of dissolved solids in runoff from undisturbed (W6) and deforested (W2) watersheds of the Hubbard Brook Experimental Forest. Values in metric tons/km²-yr (metric tons/km² × 10 = kg/ha).

CHEMICAL	1966-67		1967-68		1968-69	
	W6	W2	W6	W2	W6	W2
Ca	−0.8	−7.5	−0.9	−9.0	−1.0	−6.8
K	−0.1	−2.3	−0.2	−3.6	−0.2	−3.3
Al	−0.1	−1.7	−0.3	−2.4	−0.3	−2.1
Mg	−0.3	−1.6	−0.3	−1.8	−0.3	−1.3
Na	−0.6	−1.7	−0.7	−1.7	−0.6	−1.2
NH_4	+0.2	+0.1	+0.3	+0.2	+0.3	+0.2
H	+0.1	+0.07	+0.09	+0.05	+0.08	+0.04
NO_3	+1.5	−43.0	+1.1	−62.8	+0.5	−45.5
SO_4	−0.8	−0.5	−1.0	0	−1.9	−2.0
HCO_3	−0.2	−0.1	−0.3	0	0	0
Cl	+0.2	−0.1	0	−0.4	−0.1	−0.1
SiO_2-aq.	−3.6	−6.6	−3.6	−6.9	−2.9	−5.9
TOTAL	−4.6	−65.0	−5.9	−88.4	−6.2	−68.0

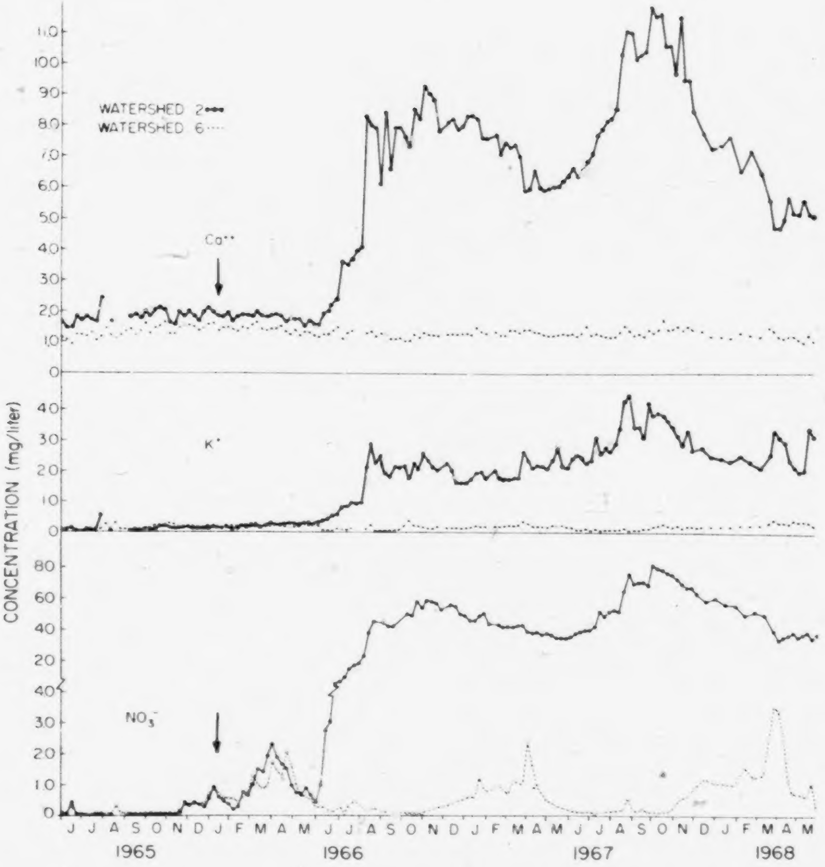

Figure 3. Measured stream water concentrations for calcium, potassium, and nitrate ions in watersheds 2 (deforested) and 6. Note the change in scale for the nitrate concentration. The arrow indicates the completion of cutting in watershed 2.

the second year, as is calculated from Table 3.[1] The average loss of nitrate nitrogen over a three-year period was about 110 kg/ha-yr. This is more than double the amount of nitrogen taken up by the undisturbed system each year. If all of the nitrogen were to come in only from precipitation and if there were no losses whatsoever, it would take about 43 years for the system to make up the amount of nitrogen lost in stream waters during these three years. If there were normal losses each year, as in the undisturbed situation, it would take about 100 years to replenish the nitrogen which was lost as a result of cutting down the trees and preventing their regrowth. What are the reasons for this?

In the undisturbed forest, decay of organic debris such as leaves, twigs, bark, etc. produces ammonium compounds. This ammonium will either be taken up directly by the vegetation or it may be converted by microorganisms to nitrate and then taken up by the vegetation and held within the system. In the absence of vegetation the ammonium compounds are converted to nitrate and leached rapidly from the system. By removing this one component, the vegetation, a major change in the basic nitrogen cycle occurred. Alteration of the basic nitrogen cycle was the major change in ecosystem function, but there were many others. (Figure 4) Some were expected, but many were completely unexpected.

The system maintains integrity by relatively simple biotic factors. These include such things as dead leaves which plaster over stream banks, or small rootlets which help to hold the stream bank in place and keep it from breaking apart and washing away. Without living vegetation to continuously resupply these dead leaves and to renew the small rootlets, the biotic regulation of erosion and transport was greatly reduced so that the output of particulate matter from the system was increased about 11 times after three years.

Along with this, the acidity of stream water greatly increased: Its pH decreased from about 5.1 to 4.3. Stream water might be characterized as a very dilute solution of sulfuric acid in the undisturbed situation, but it changed to a stronger solution of nitric acid as a result of deforestation.

The stream water from the deforested watershed appeared to be just as clear and potable as that from adjacent undisturbed watersheds. However between August 1966 and January 1970 the nitrate concentration almost continuously exceeded, and at times doubled, the maximum concentration recommended as allowable for drinking water. Thus the deforestation treatment resulted in significant pollution of the drainage stream.

Increased sunlight striking the stream in the absence of a forest canopy, the high nutrient concentrations, and higher stream temperature, all resulted in significant eutrophication. Whereas the undisturbed streams contain few algae, a dense bloom of green algae occurred in the stream of the deforested watershed each summer. This is a good example of how a change in one component of an ecosystem alters the structure and function, often unexpectedly, in other parts of the same ecosystem or in an interrelated ecosystem. Unless these interrelationships are understood, naive management practices can produce unexpected and possibly widespread deleterious results.

THESE results pose some very important questions for forestry management. Clear-cutting of forest vegetation is practiced widely in the United States, but there are few data on its total effect on the ecosystem. To our

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[1] This is done by using the formula $NO_3 \times 0.226 = N$.

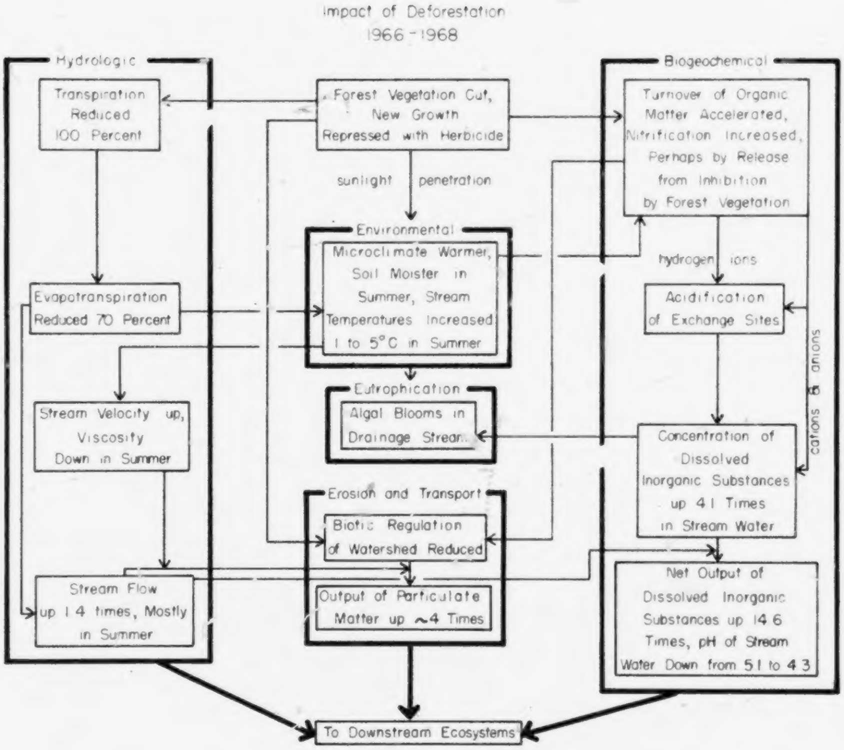
Impact of Deforestation 1966 - 1968
Hydrologic
Transpiration Reduced 100 Percent
Forest Vegetation Cut, New Growth Repressed with Herbicide
Biogeochemical
Turnover of Organic Matter Accelerated, Nitrification Increased, Perhaps by Release from Inhibition by Forest Vegetation
sunlight penetration
Environmental
Microclimate Warmer, Soil Moister in Summer, Stream Temperatures Increased 1 to 5°C in Summer
hydrogen ions
Evapotranspiration Reduced 70 Percent
Acidification of Exchange Sites
cations & anions
Eutrophication
Algal Blooms in Drainage Stream
Stream Velocity up, Viscosity Down in Summer
Concentration of Dissolved Inorganic Substances up 4.1 Times in Stream Water
Erosion and Transport
Biotic Regulation of Watershed Reduced
Output of Particulate Matter up ~4 Times
Stream Flow up 1.4 times, Mostly in Summer
Net Output of Dissolved Inorganic Substances up 14.6 Times, pH of Stream Water Down from 5.1 to 4.3
To Downstream Ecosystems

Figure 4. A summary of some of the ecological effects of deforestation in the Hubbard Brook Experimental Forest. The forest was cut in the autumn of 1965.

knowledge there are no other quantitative data on chemical losses from cleared forests. Since the deforestation treatment was done as an experiment, logging roads were not constructed, timber was not removed, and herbicides were used to prevent vegetation regrowth. However preliminary results from studies now in progress on a number of commercially logged areas in northern New England clearly show the same pattern of nutrient loss and eutrophication in drainage waters as that which occurred in the experimentally deforested watershed.

If recharge of nitrogen is solely dependent upon input in rain and snow, decades would be required to replenish the nitrogen lost as a result of clear-cutting. How does this affect long-term productivity of the forest? Are there other mechanisms of nitrogen replenishment? We don't know. Neither do we have good information on regrowth in old roadbeds or even good information on the role of noncommercial forest species in the function of many forest ecosystems.

Perhaps the greatest damage done to lands is that done by road building. Breaking of forest cover by road building is a double threat. Roads open land to erosion, which is the primary enemy of the forest ecosystem, and space consumed by roads is taken out of production, or subsequent production may be very low on abandoned roadbeds. As much as 20 percent of a forest ecosystem may be consumed in road building. This could remove 20 percent of the area from future production.

The application of herbicides to the deforested watershed now has been stopped, and the vegetation is becoming re-established. Studies of revegetation in combination with the study of nutrient flux using the watershed-ecosystem concept are providing some very valuable ecological information. Ecosystem recovery, including the maintenance or re-establishment of regulating mechanisms, is of vital interest to managers and conservationists. We need to know how, and at what speed, ecosystems can recover, or regain ecological balance, after serious external manipulations.

In cooperation with the U.S. Forest Service, we have undertaken a number of other experiments to elucidate the behavior of an ecosystem under stress, in an attempt to develop sound management practices for landscapes. One watershed was commercially clear-cut and another was commercially strip-cut during 1970. (Figure 2) Alternate sets of horizontal strips cut on the latter watershed will clear the watershed of harvestable timber in four years. A small buffer strip remains uncut along the stream. This is an attempt to develop a forest management scheme without the nutrient-dumping effects associated with clear-cutting. These experiments will evaluate effects on production of stream water, nutrient losses in stream water, and regeneration of the forest.

The studies at Hubbard Brook illustrate ecological interactions of the structure and function of a northern deciduous forest ecosystem. They also reinforce the suggestion of many ecologists that the ecosystem concept is a powerful analytical tool for producing and testing management strategy. The ecosystem concept provides the best way of seeing nature whole and provides a realistic scheme for ecologic bookkeeping. ☐

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A HYPOTHETICAL CONTINENT—TEACHING THE "WHERE" AND "WHY" OF CLIMATES

Don Goldman

AT FIRST glance, the world map of climates seems a confusing jumble. The confusion can be dispelled, however, if several basic principles are understood. Climates are not randomly or accidentally distributed; there is a logical, predictable arrangement that results from the actions and effects of a few global climatic controls. Therefore, the world pattern of climates can be made quite manageable, providing the teacher does three things:

1. Stress the few major elements that largely determine global and continental climatic differences and not burden the student with myriad facts that are relevant but unnecessary.
2. Lead the student through a series of logical steps, each of which expands on the preceding one and sets the stage for the next.
3. Generalize, that is, avoid the perplexity of details and exceptions.[1]

Try using a hypothetical continent to teach the distribution of climates on the world's land surfaces.[2] This stylized continent approximates the actual world distribution of land in that there is more land area in the Northern Hemisphere than in the Southern, and it extends farther poleward, but it is a gross generalization. It has no mountains, irregular coasts, or interior bodies of water. In other words, it provides us a simplified platform upon which we can trace the relative location of the main climatic types as they are determined by global controls, minus the complexities caused by landform, altitude, and other local factors. After these relationships are understood, the students can then compare the hypothetical pattern with the climatic pattern of the real world.

The following is a three-step classroom presentation employing this concept. It moves from the general and simple to the detailed and complex, from the hypothetical and conceptual to the real and familiar. In the first step the previously studied climatic controls are superimposed one atop the other so as to illustrate their individual and composite influence.[3] The result is a distribution of climates on our hypothetical surface. Second, the teacher moves to a real climate map of North and South America and shows how the hypothetical pattern holds, with minor adjustments. Finally, the class looks to the rest of the world, observes the still clear adherence to the pattern, and considers the logical reasons for the major departures.

THE FIRST principle in climates is that, on an annual basis, the equatorial regions receive the most solar heating, the poles receive the least, and there is a more-or-less continuous gradient between them. Considering only this one factor, *heat*, we can illustrate the decrease from equator to pole with a series of five east-west zones, each of which can best be described by the presence or severity of winter.[4] As shown in Figure 1, these zones are:

Tropical zone:	*No* winter
Subtropical zone:	Mild winter (occasional frost)
Temperate zone:	Pronounced winter
Boreal zone:	Severe, long winter
Polar zone:	*Always* winter

Except that the boundary lines of these zones are somewhat curved, reflecting the effects of a continental landmass, we have here the simple worldwide pattern of roughly parallel bands of heat distribution as superimposed on the continent. It shows us only where it is hotter and where it is colder, as determined by latitude.

The second major factor of climate is precipitation or, conversely, *dryness*. In contrast to the almost complete latitudinal control over heat zones, clearly something else affects the location of the world's dry zones. (Figure 2) It will be remembered that there is a general subsidence of air at about latitude 20° to 30° north and south that causes a series of high pressure cells (subtropical anticyclones) over the oceans. The phenomenon of subsidence is antithetical to precipitation (which requires *rising* air), and the strongest development of this subsiding air is in the eastern part of the anticyclones, *adjacent to and overlapping the western coasts at that latitude*. This explains the aridity of the low latitude west coasts of the hypothetical continent. The eastward and poleward swing of the arid zone is a blend between that condition and two interior conditions: the increasing distance from oceanic

The author, formerly a recreation resource planner with the Bureau of Outdoor Recreation, Department of the Interior, Washington, D.C., is serving with the Peace Corps as a planner with the Costa Rican National Park Service.

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[1] It is assumed that the student will have been prepared for a study of the location of climates with prior class work on such basics as the inclination of the earth's axis and the resultant concept of seasons, the uneven heating of the earth's surface and the resultant pressure zones and winds, the nature of precipitation and its causes, and types of weather.

[2] The accompanying diagrams of a hypothetical continent are taken, with slight modification, from Trewartha, Robinson, and Hammond, *Elements of Geography*. Fifth Edition. McGraw-Hill Book Company. New York. 1967.

[3] Graphically, this technique can be handled variously: (a) As a single visual aid showing the completed hypothetical continent, as in Figure 3; (b) as three different aids, as per Figures 1, 2, and 3; and (c) using Figure 1 as a base on stout illustration board with Figures 2 and 3 as transparent overlays.

[4] I use the climates as classified in *Elements of Geography, op. cit.* Each bounding line between two climates is precisely defined according to that system (i.e., the boundary between the subtropical and temperate climates is where eight months have an average temperature of 50°F). Such precision is completely unnecessary in an introductory classroom presentation; verbal descriptions of the climates will convey the point. Also, any other classification system can be illustrated with a hypothetical continent, so long as the boundary lines of the diagram conform to that system.

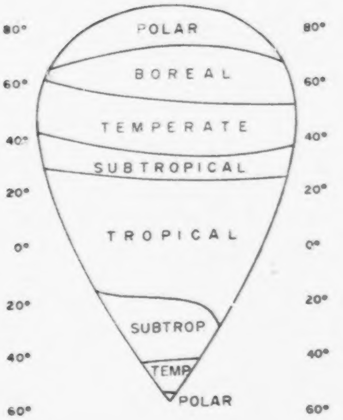

Figure 1. *The hypothetical continent can be divided into five east-west zones by the amount of solar radiation received.*

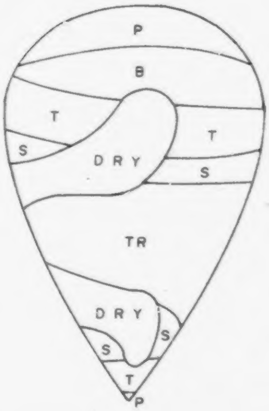

Figure 2. The second major factor of climate is precipitation or, conversely, dryness. This can be superimposed on Figure 1.

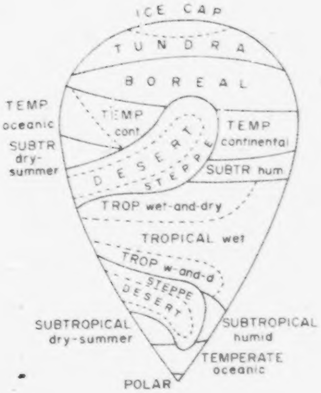

Figure 3. The hypothetical continent can be refined to provide a system consisting of 11 distinct climatic types, as indicated.

sources of moisture and the winter anticyclone of the northern interior. Note that the arid zones do not reach the east coast. Whereas the east part of the subtropical anticyclone is strongly developed, the western end (adjacent to continental east coasts) is quite weak, and its onshore winds contain considerable moisture.

We now have a framework. But climate is a multifaceted thing—it is a description of the place where we live, a major part of our environment. It includes the seasonal distribution of precipitation, as well as its amounts; it includes the extremes of temperature, as well as the averages. In further refining the five temperature zones and the one arid zone into a meaningful classification system, *relative location* on the hypothetical continent must be considered. We will see, for example, that the opposite ends of the subtropical zone, while sharing similar *temperature* characteristics, have sharply different precipitation patterns, and that this becomes the distinguishing mark between the two subtropical climatic types. The resultant subdivisions provide a system consisting of 11 distinct climatic types which bear, as we shall see, a consistent relationship to their continental locations and to one another. (Figure 3)

Tropical zone: The tropical zone is always hot. Its rainfall is controlled by the broad band of the intertropical convergence (the converging NE and SE trade winds, a zone of rising air), and this zone of converging and rising air follows the overhead sun in its swing back and forth between the Tropics of Cancer and Capricorn. In this swing, the broad band of resulting convection rains always covers the *core* of the tropical zone, but it leaves the northern and southern margins dry during their respective low sun periods.

1. *Tropical wet climate* (or Rainforest). Located along the equator at the core of the tropical zone. Always hot and almost always rainy, precipitation is from convection showers that come with the heat of the afternoon.
2. *Tropical wet-and-dry climate* (or Savanna). Also always hot. But located to the north and south of the core, it is rainy only during the high sun period, at which time it is similar to the tropical wet. During the dry months, which number from two to five or more, it is like a desert.

Dry zone: At its core, where the effects of the subtropical anticyclone are strongest (west coasts) or where distance from ocean sources is greatest (interiors), are the deserts. On the fringes are the steppe regions, transitions to the humid climates.

3. *Desert climate* (or arid)
4. *Steppe climate* (or semiarid)

Subtropical zone: This zone has two distinct climatic types, dependent on their eastern or western location on the continent.

5. *Subtropical humid climate*. Located on the east under the weak end of the subtropical anticyclone. No dry season.
6. *Subtropical dry-summer climate* (or Mediterranean). Mild, moderately humid winters, due to the equatorward migration of the midlatitude storm belt; and desert-dry in summers, when it is controlled by the strong eastern end of the anticyclone.

Temperate zone: Although this zone has a pronounced winter throughout, there is again a strong difference between eastern and western locations.

7. *Temperate oceanic climate*. Located with exposure to the western ocean, off which blow a succession of midlatitude storms, these areas have moderate to heavy precipitation and moderate winters.
8. *Temperate continental climate*. Being more distant from the ocean, this area is less modified by it; therefore it has more severe winters and receives less precipitation.
9. **Boreal zone:** Found only in the Northern Hemisphere, this climate has long, bitter winters and short, cool summers. (No subdivisions)

Polar zone:

10. *Tundra climate*. Although there is no true summer, this equatorward section has at least a brief thaw.
11. *Ice-cap climate*. Always frozen.

Figure 3, then, is a composite picture of the relative location of each climate type on our hypothetical continent. It reflects the interacting roles of the major climatic controls: the declining heat from equator to pole, the varying effects of the midlatitude anticyclone, the seasonal shift of both of those, and the varying effects of location on the continent. But how does it compare to a *real* continent?

BEGIN with that which is most familiar, the Americas. Clearly, and notwithstanding some evident differences, the hypothetical pattern fits the real land. Equally important, the departures can be seen as logical and predictable results of geographic factors.

The similarity is apparent from a simple side-by-side comparison of a climatic map of the Americas and Figure 3. It can be further illustrated by superimposing on Figure 3 a series of landmarks, each of which bears a popular climatic identity (i.e., Yuma = desert) and a recognizable geographic location. (Figure 4)

What about the *differences* between the Americas and the hypothetical continent? For example, the desert and steppe climates on the hypothetical continent sweep far east and far poleward, but in North America they hug close to the Pacific coast, lying between the temperate oceanic and temperate continental climates. This is plainly the result of the high and continuous mountain chains that characterize the Pacific coast; the rain shadow of these mountains "pulls" the drylands in close to their leeward (eastern) sides. Then again, the arid region of Argentina, which is partly a rain shadow of the Andes, extends all the way to the east coast, whereas on the model (and in North America) it remains well inland. This is simply a function of the narrowness of South America at that latitude; its width is less than that of the dry region. For the same reason, there is no area of temperate continental climate in South America. Were the continent wider at that point we could logically expect, as in the North American pattern, that a fuller extent of desert and steppe lands would give way on the east to a region of temperate continental, which would extend to the Atlantic coast.

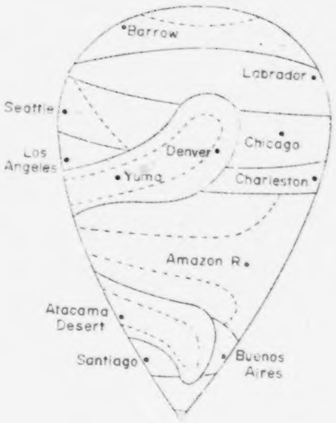

Figure 4. One can compare the hypothetical continent to the real land by indicating on the continent a series of landmarks, each bearing a popular climatic identity. Students will enjoy trying to explain differences between the predicted and the actual climates of some locations.

Looking elsewhere we find further confirmation of the hypothetical pattern. Northwest Europe, unlike North and South America, has no mountain barriers near the coast to confine the temperate oceanic climate, with the result that it extends entirely across Great Britain and the north European plain to merge gradually (with no intervening rain-shadow–induced dry region) with the temperate continental climate. Similarly, the vast extent of North African-Eurasian drylands closely approximates the hypothetical pattern, with distance from the source of moisture assuming great significance on that huge land mass.

Exceptions also occur. For example, whereas the subtropical dry-summer climate is narrowly confined to coastal locations by the North and South American mountains, the great open extent of the Mediterranean basin brings this climate all the way to the Middle East. In Africa and Australia, the subtropical dry-summer climate occupies slightly unusual locations, but again this is explained by geography, in these cases the configuration of the coasts. In the former, the southern tip of Africa just barely extends into the latitude of dry summers, so this climate occupies the southern tip of the continent, rather than the expected west coast location. In the latter, Australia has *two* southern tips, both of which reach into the critical latitude. Not surprisingly, even the eastern one, which is some 2,000 miles from the west coast, has dry summers, but only on *its* west coast (around Adelaide).

Finally, there are no areas of boreal climate in the Southern Hemisphere because none of its land masses extends to a high enough latitude.

AS DESCRIBED in the foregoing, the climate of a place is to a marked degree determined by its specific location on a continent, and it is that characteristic that is best illustrated by the hypothetical continent as shaped and described here. For the same reason, and because of the close relationship of soils and vegetation to climatic types, this technique can also be utilized in teaching the geographic distribution of soils and natural vegetation.

The hypothetical continent is a stylized, gross generalization. One of its valuable characteristics as an instructional tool is that the teacher can "sketch" broad concepts or relationships on it without being inhibited by the myriad details and exceptions of the real world. For one example, the place names of Figure 4 are only a rough approximation of their true geographic locations, yet their collective effect is a clear representation of their *relative* locations. For another, the teacher might draw a north-south trending mountain range in the western part of Figure 3, thereby graphically showing how the barrier effect of the mountains and the resultant rain shadow change the pattern of climates from that of the hypothetical continent to that of the North American map. Other innovations or applications will undoubtedly occur to the teacher. □

INVENTORYING SOIL RESOURCES

F. L. Himes

THERE may be almost as many different kinds of soils as there are plants that live upon them. Each soil has a distinctive set of properties which are derived from the starting (parent) material and environment. Soil is more than disintegrated rock; during its formation, materials have been added and others have been removed. Plants and animals have added organic compounds and altered the physical properties of the parent material. Climate influences not only the rates of chemical weathering, leaching, and erosion, but also the type and rate of biological activities. Land relief and time of exposure are the other factors that account for variations among soils.

Why has man divided soils into groups? He has found that one soil is better suited to a particular use than are others. Light-colored soils are usually lower in fertility than are the associated dark-colored soils, but they do not require artificial drainage. Sandy soils have a lower water-holding capacity than clay soils. Light (sandy) soils are easier to cultivate than heavy (clay) soils. Very acid soils are suitable for certain plant species, but near neutral soils are best for most. Well-drained soils are more desirable than poorly drained ones for home construction, road construction, and playgrounds.

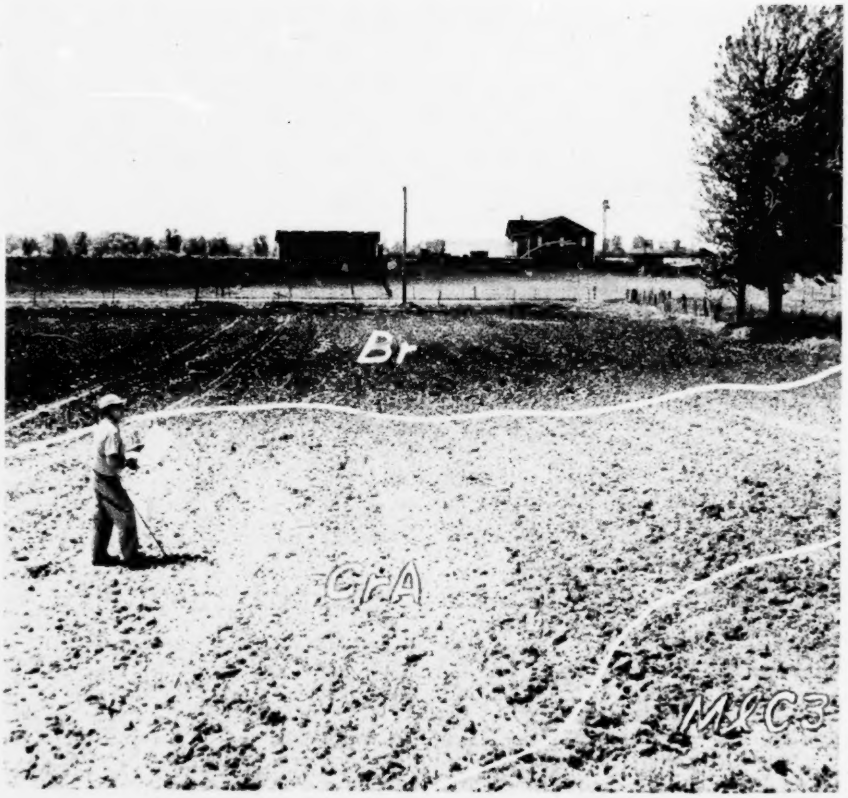

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Figure 1. Lines may be drawn on a soil survey map to illustrate horizontal differences among soils. Brookston (Br) is a silty clay loam with high water table part of each year and poor natural drainage. Crosby (CrA) is a silt loam with drainage intermediate between Brookston and Miamian; land slope is 0 to 2 percent. Miamian (MIC3) is a clay loam; severely eroded; good natural drainage; land slope is 6 to 12 percent.

Making an inventory of the soils of an area includes locating the boundaries between soil types and measuring properties of samples from each soil. The boundaries between soils frequently coincide with changes in colors. These color changes within a field occur when changes in slope (relief) affect soil moisture and erosion. They are also influenced by the parent material (original mineral material) and vegetation or a combination of these. Climate and time, too, contribute greatly to horizontal differences among soils. In the humid climatic regions, soils with poor natural drainage have

Dr. Himes is professor, Department of Agronomy, The Ohio State University, Columbus.

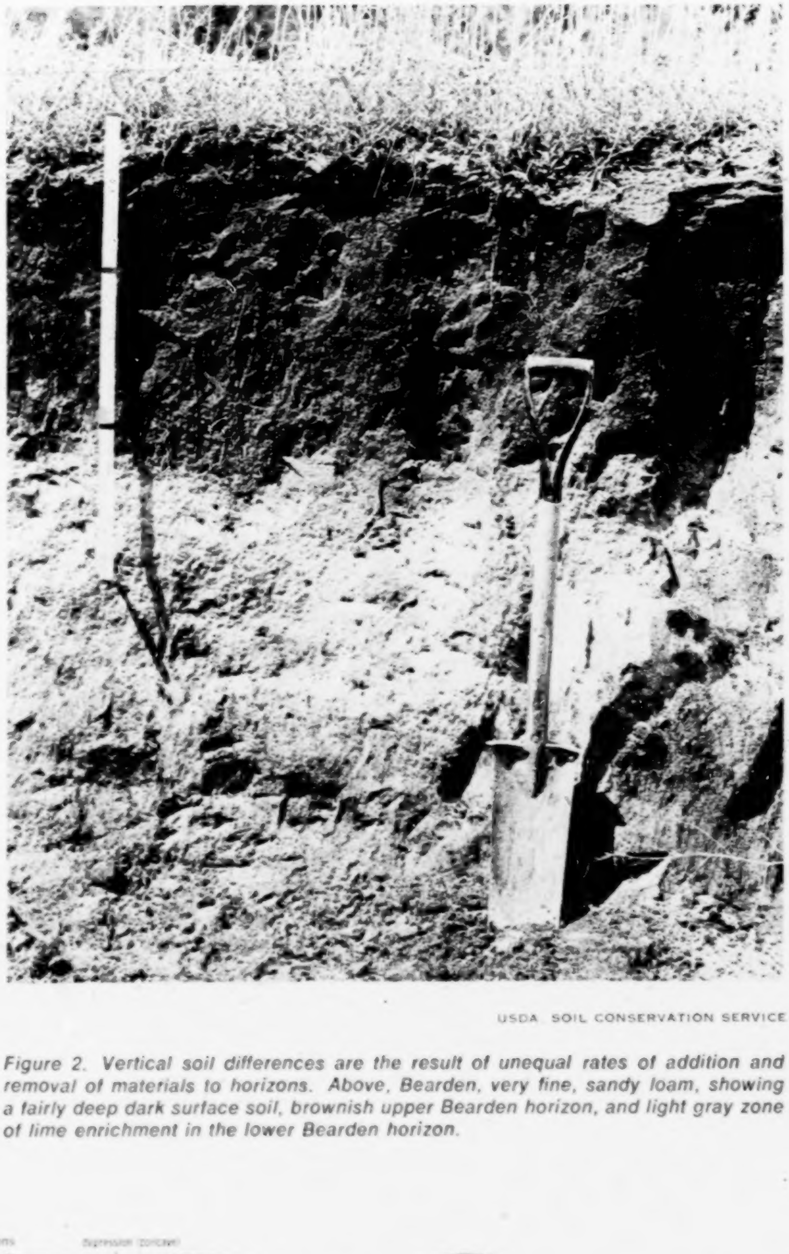

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Figure 2. Vertical soil differences are the result of unequal rates of addition and removal of materials to horizons. Above, Bearden, very fine, sandy loam, showing a fairly deep dark surface soil, brownish upper Bearden horizon, and light gray zone of lime enrichment in the lower Bearden horizon.

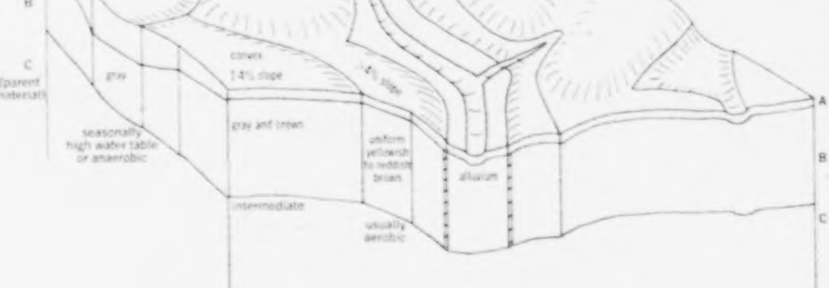

Figure 3. Landscape in a humid, temperate region where forest was the natural cover.

a darker surface color than that of the well-drained soils. This darker color results from the higher concentration of humus. Soils in depressions or with an impermeable layer are poorly drained. Drainage systems must be installed in these soils before they are satisfactory for growing many species of plants, or for building houses, constructing roads, and developing athletic fields. In arid regions salts, transported from the sloping areas by leaching and erosion, accumulate in the depressions, and the soils often have a white color.

The Soil Profile

A vertical section of soil, or profile, usually shows three layers known as horizons. The horizons can be identified by color changes, by texture, and/or by structure. The topsoil or surface mineral layer is the *A*-horizon, the subsoil is the *B*-horizon, and the parent material is the *C*-horizon.

The *A*-horizon is the layer of soil that supports plant and animal life. The *A*-horizon tends to be sandy or silty if the clay has been transported into the *B*-horizon. Soluble mineral matter likewise leaches downward. Organic material or *humus* from decayed plants and animals makes this layer darker than the *B*-horizon below it.

The internal movement of water and the oxidation conditions of soils in humid regions can be determined by observing the color of the iron oxides in the subsoil or *B*-horizon. Soils with rapid internal water movement have a uniform yellowish-brown to reddish-brown color in the *B*-horizons; those with slow internal water movement have uniform gray colors. Soils between these extremes have mottled (yellow and gray) *B*-horizons. The poorly drained soils also have higher concentrations of organic matter to greater depths than have the better drained soils.

The *B*-horizons of most soils are zones of accumulation. Soils formed under acid conditions have an accumulation of clay and/or iron and aluminum oxides. The accumulation of clay can be detected by feel, as will be described. The increased concentration of iron oxides can be observed by the

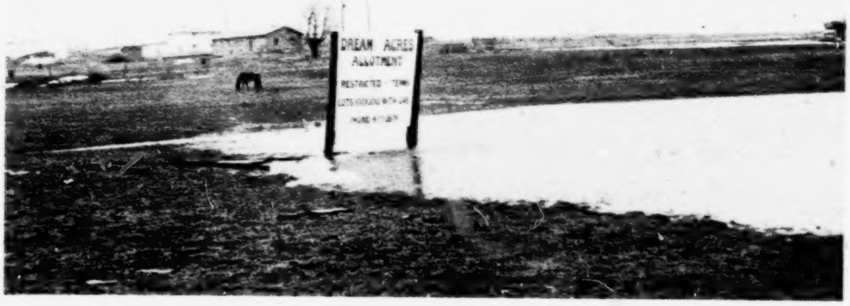

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Figure 4. Sites for housing and other uses should be inspected during a wet season.

increased brightness of color. In arid and subhumid regions, calcium carbonate accumulates in the *B*-horizon. This occurs as a white layer and varies from a soft and discontinuous layer to the very hard and continuous crust known as caliche. The accumulation of materials in the *B*-horizon can decrease the rate of water movement, restrict root growth, and increase the energy required to dig holes and foundations. The decrease in water transmission must be considered when designing drainage fields for septic tanks.

The *C*-horizon is the parent material. The parent material may be bedrock (residual) or unconsolidated material. The latter has usually been transported to the site by water, ice, wind, or gravity. At soil age zero, the surface layer was similar to the *C*-horizon. During soil formation, the compositions of the upper layers changed because of various removals and additions. The *C*-horizon contains the material that has undergone little or no change during the development of the *A*- and *B*-horizons.

A soil sample can also be inventoried for physical, chemical, and biological properties. The procedures for determining these properties vary from qualitative to quantitative. Some procedures will be briefly described.

Physical Properties

Soil particles are graded by size (from coarse to fine) as sand, silt, or clay. Since most soils are mixtures, the *texture* of a soil is determined by the relative proportions of these particles. On the basis of texture, soils are divided into large classes: sands, loams, silts, and clays. Soil scientists want to know the textural class of a soil before making a management recommendation.

The textural class can be determined qualitatively by feel. The sample is moistened to the consistency of putty and forced into a thin ribbon between the thumb and forefinger. If the soil has more than 40 percent clay, it will form a long, thin ribbon and is classified as clay. Soils with 27 to 40 percent clay will form shorter ribbons and are called clay loams. Soils containing less than 27 percent clay will not form a thin ribbon and are called loams. Each of these classes can be subdivided; for example, into sandy loam and silt loam. Quantitative methods are described in references 1 and 3.

The arrangement of the soil particles influences the rate of water infiltration and percolation, the movement of gases, and root development. Soil *structure* refers to the arrangement of soil particles into aggregates. The size and arrangement of soil particles and aggregates are important in determining the size and shape of pore spaces. Pores may contain air or water or both. Granular (spherical) structure is preferred for root development, water movement, and water retention. The large pores between aggregates permit rapid movement of water, and the small pores within the granules retain water for later use by the plants.

A soil crust is a thin, close-packed structure on the soil surface which greatly restricts the infiltration of water and the diffusion of gases to lower layers of the soil. Clay pans, fragipans, and caliche occur below the surface (usually in the *B*-horizon) and restrict water movement and root penetration. Another structure that retards water and root penetration is platy; platy structural units overlap like shingles.

Common structural forms in the *B*-horizons are blocky, prismatic, and columnar. As the cross-sectional area of the aggregates decreases, the number of vertical pores per unit area increases. The rate of percolation and ease of root penetration increase with the number of vertical pores.

The *quantity of water* in a sample can be determined by weighing it before and after drying. Soil samples are usually dried at 105°C.

$$\text{Percent water} = \frac{\text{wt. of water}}{\text{wt. of dry soil}} \times 100$$

This laboratory procedure can be used to compare the moisture content of many soils (poorly drained vs. well drained, *A*-horizon vs. *B*-horizon) and the change in moisture content with time after the addition of water.

The *rates of water movement* can be determined as illustrated in Figure 1.

The rates of movement differ among soils, among horizons, and with past treatment. On sloping sites, water runoff occurs when the rate of rainfall exceeds the rate of infiltration.

In urban areas, construction sites are a major source of sediment in streams. There is increased erosion from such sites because the surface layer has been compacted, decreasing the rate of infiltration and increasing runoff.

The volume of the particles in a sample can be determined by displacement of water. *Particle densities* (D_P) do not vary much from mineral soil to to mineral soil. *Bulk densities* (D_B) do vary greatly and are calculated by the following formula:

$$D_B = \frac{\text{wt. of dry sample}}{\text{vol. of sample (or vol. of pores + vol. of particles)}}$$

One common method for determining the bulk density is to force a sharp-edged, metal cylinder or can with both ends removed into the soil. After the soil is trimmed to the volume of the cylinder, it is dried and weighed, and the volume of the cylinder is calculated. Care must be taken to avoid compaction during collection of the sample.

Bulk densities not only vary among soils but also among horizons and with use. For example, compare a sample from a footpath with a sample taken 10 feet away. Most plant roots will not penetrate a layer if the bulk density is greater than 1.6 g/cm^3.

The percent *pore space* can be calculated with the following formula:

$$\text{Percent pore space} = 100\% - (D_B / D_P \times 100)$$

The surface layers of productive agricultural soils have approximately 50 percent pore space, or a bulk density of approximately 1.3 g/cm^3.

Chemical Properties

A useful and easy chemical determination is *soil acidity* or *alkalinity* as measured by pH. The pH of soil samples can be determined by the use of color indicators and pH meters. Variations in pH occur among soils, among horizons, and with past treatments. Soil pH is often changed by farmers and gardeners. The optimum pH range for many species of plants is near neutral, that is, 6.2 to 7.0. Some of the favorite flowering shrubs (e.g., azaleas) grow best in the acidic range of pH 4.5 to 5.0.

Clay particles and organic colloids are negatively charged and attract the cations. The larger the *cation exchange capacity* (CEC), the greater buffering capacity, or ability to protect from major change in pH. Larger quantities of fertilizers and amendments can be more safely applied to soils with large CEC than to those with low CEC.

The cation exchange capacity of a soil must be known for efficient use of soil and fertilizers. One procedure for determining the CEC of soil is described below:

1. Weigh 10.0 g of soil into a 125 ml Erlenmeyer flask.
2. Add 50 ml of approximately 1 N HCl. Shake for 10 minutes.
3. Let the soil settle, then decant most of the supernatant liquid through a filter paper; discard the leachate; and repeat acid leaching.
4. Shake the soil with 50 ml of distilled water for one minute. Let the soil settle, and decant the supernatant liquid through the filter. Repeat this step two more times. Discard the leachate. Place filter paper and soil in flask.
5. Add 50 ml of 1 N barium acetate. Shake occasionally for five minutes. Let the soil settle and decant the supernatant liquid through the filter, collecting the filtrate in a clean 250 ml suction flask. Repeat this step, collecting the filtrate in the same flask.
6. Add 20 ml of distilled water to the soil, shake, let the soil settle, and decant through a filter, collecting the filtrate in the same container as used in step 5.
7. Add a few drops of phenolphthalein indicator solution and titrate with NaOH. Record the volume and concentration of NaOH used on the data sheet and calculate the milliequivalents of exchangeable cations per 100 g of soil.

The concentration of *organic matter* can be determined by loss of weight. The organic matter can be oxidized with hydrogen peroxide or by heating to 550 C. Increasing the concentration of organic matter increases the CEC, the water-holding capacity, the biological activity, and the release of available nitrogen in soil. Organic matter will adsorb many pesticides. It is recommended that some pesticides not be added to soil with more than 5 percent organic matter because the pesticide will not efficiently control the pest.

Available phosphorus and potassium can be determined by the procedures described in soil analyses books and in soil test kits.

Many *minerals* of the sand fraction can be identified by examining the sand grains with a microscope. Mineral soils that shrink upon drying, developing large cracks, usually contain the clay mineral montmorillonite.

Biological Properties

The distribution of plant roots in the soil can be determined by carefully washing the soil particles from the roots. Roots of representative volumes can be compared by taking cores at various distances from the base of the plant. The roots are usually weighed after drying at 70 C. Small animal populations can be determined by using the Berlese funnel technique. The bacteria and fungi populations can be determined by suspending a sample of soil in sterile water, diluting, and adding to the proper agar mixture for culturing. The number and types of organisms vary with such factors as pH, aeration, temperature, and quantity of food.

Summary

Soil varies horizontally and vertically. The horizontal changes are associated with changes of slope, vegetation, parent material, climate, and time. The vertical differences on a soil profile are the results of unequal rates of addition and removal of materials to horizons. For efficient use of a unit area of soil, a manager needs to know the surface and internal water movement characteristics, the textural class, the structure, the bulk density, the pH, the cation exchange capacity, the percent organic matter, and the types of pathogenic organisms. The boundaries and properties of soil types in many counties can be obtained from the detailed Soil Survey Reports published by the Soil Conservation Service of the U.S. Department of Agriculture. □

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GENERAL

Survival City: An Environmental Awareness Project

THOMAS R. BREHMAN, Science Teacher, Maine Township High School North, Des Plaines, Illinois, and MUSA QUTUB, President, Illinois Earth Science Association, and Assistant Professor of Earth Science, Northeastern Illinois University, Chicago

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SURVIVAL CITY

The world's fossil fuels had been totally depleted back in 1988. Long-term predictions regarding the collapse of agricultural soils through overuse of inorganic fertilizers came to pass four years later. In 1997 began the terminal stages of the eutrophication of Lake Superior, last of the fresh-water basins in the United States. By the turn of the century, millions of urban dwellers had succumbed to the toxic fumes in their city air.

Now, in 2009, man must live within protective domed cities in order to survive. There is no safe air to breathe or water to drink outside the domes. If we are to survive we must be able to exist within a closed-system complex.

You as a team are commissioned to design and construct such a habitat. Two other groups have also been designated for similar proposals. The awarding of the contract will be based on a feasible plan for solving the problems inherent in such a project. Money is not a factor—all expense will be absorbed to aid man to survive as a species.

The above problem was presented to three tenth-grade science classes as part of a unit on ecology and the environment. Four weeks were alloted for completion of the "Survival City" project.

Each class had to design and construct a three-dimensional, domed metropolis complex, complete with maps indicating lines of transport, communications, and public utilities. Architectural drawings were developed illustrating the physical layout for power and ventilation, and food, water, and oxygen-production facilities. Construction materials for housing, factories, and the actual dome had to be researched. Waste disposal alternatives had to be evaluated, and the amount of land needed to support such a domed complex had to be computed. Students in each class appointed subcommittees to supervise scale agreement for each building contained in Survival City.

Numerous problem-solving situations were confronted by students choosing to deal with the theoretical and social ramifications of the project. Committees investigated: oxygen potentials of algal "mass cultures"; nuclear-power capacities of breeder reactors; optimum population size as a function of individual space requirements; projected plans for food synthesis from soya beans and other plant materials; most desirable form of governmental organizations; and psychological impact of confinement within a closed system.

Such considerations may seem straightforward; others, however, are not readily apparent. For example, one class chose to have recreational parks and forested sections—but which plants and animals should be brought into the closed environment? (It was presumed that all others would perish outside the dome.) A desire for plants that depend on certain insects for completion of their life-cycle necessitated inquiry into plant-insect relationships. This led to further research concerning insect-insect and insect-microbe dependencies. On learning of these difficulties, another class decided to use artificial vegetation to "beautify" its metropolis. It then had to contend with animal requirements for digesting plastic flora, to say nothing of the psychological stress of never again smelling a rose or newly cut grass.

Multidisciplinary inquiries into such fields as nuclear power, construction and sanitary engineering, biological relationships, psychology, population dynamics, political and economic sciences, and human physiological adaptations became essential. More important, the students readily saw the interdependencies of these fields of study, and the project soon involved other teachers. For example, in a history class the students formulated a constitution applicable to living within "Survival City." The English teacher provided enrichment assignments by having students write newspaper articles describing various aspects of life in their domed city. Basic designs for the dome and city planning were discussed in geometry class. The study demonstrates how barriers between the natural and social sciences can be removed in order to provide alternative answers to environmental problems that may soon confront us.

Students were given the opportunity for creative problem solving and responsible decision making. But what role did the teacher play? The answer—none. The science teacher served only as a reference person, though aware of all outstanding problems and courses of action by consulting the weekly progress reports of each committee.

Through Survival City, students discovered for themselves some of the physical and social possibilities and limitations of living within the closed system that constitutes the earth. Ultimately, is this not the prime objective of an education? ☐

High school students were asked to design and construct a three-dimensional, domed metropolis in which man could survive if the outside environment were so polluted as to be uninhabitable. The project tore down barriers between the social and natural sciences and gave students some inkling of the complexity of the biosphere.

The Ecology of Sand Dunes

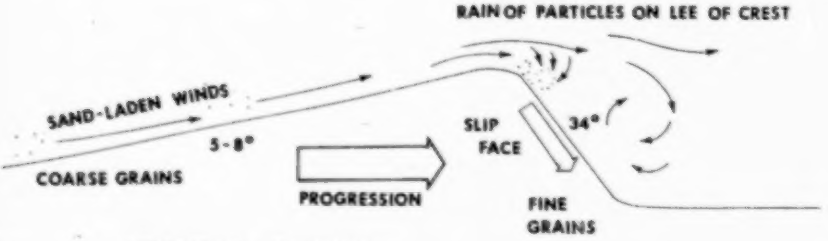
WILLIAM H. AMOS
Chairman, Science Department
St. Andrew's School
Middleton, Delaware, and
Research Associate
Marine Laboratory
University of Delaware, Newark

ONE of the problems with introducing an ecological study to first-year biology students is the welter of obscuring and conflicting detail. Identifying determining factors in most habitat studies requires a trained and selective eye, long and concentrated effort, and too often, arbitrary restrictions. Woodlots and meadows are complex; ponds are even more so. The marine shoreline is almost infinitely variable. But a relatively pristine habitat exists in the sand dunes of lake and coastal shores. Even sandy patches in old lots or along roads have many of the characteristics of a dune.

A sand dune offers a number of advantages for student investigation. Its paucity of biotic factors presents a challenge, yet for most visitors dune-walking has elements of pure pleasure. What makes dunes worthy of attention? Their structure is simple, for they are composed of particles of fairly uniform size. The highly reflective surface of sand may provide extreme, even lethal, temperatures, but subsurface and aerial temperature gradients are easily measured and reveal their own zonation of life. A dune holds little moisture or organic nutrients; it is altered visibly by physical forces, such as wind and rain; and it is sparsely inhabited by only a few species of organisms. A sand dune shows at any one time both zonation and a serial biotic succession extending from shifting, abiotic sand to stabilized, vegetated, sand-humus hillocks.

Inland sand dunes form when masses of sand are blown from a continuing source of supply, usually a beach. Once large enough, they move slowly over field and forest, marsh and stream. A profile of a dune usually reveals a gentle windward slope, a crest, and an abrupt slipface which plunges down from the crest to the land being covered. On a windy day grains can be seen being blown along the windward rise until they reach the crest, where turbulence causes them to roil about, then drop down in the lee of the dune. The slipface constitutes an angle of repose, 33 to 34 degrees. Any tendency to increase this angle causes grains to slip on one another, thus advancing the whole front. While wind forces and inhibiting factors vary, some dunes may flow over a hundred feet in one direction a year, notably those along the Bay of Biscay and near the Salton Sea. Those near Provincetown, Cape Henlopen, and Nags Head travel more slowly.

Above: slipface. Below: A dune such as that diagramed may advance nearly 100 feet a year; its crest can be 60 or 80 feet above the land over which it travels. The dynamic nature of such a dune usually prevents stabilizing vegetation from rooting.

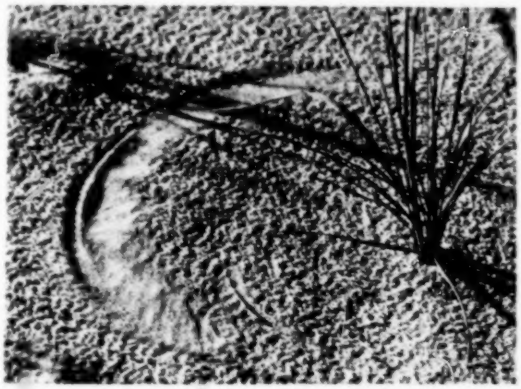


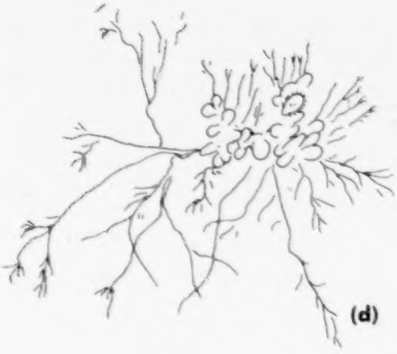
LARGE DUNE — DYNAMICS

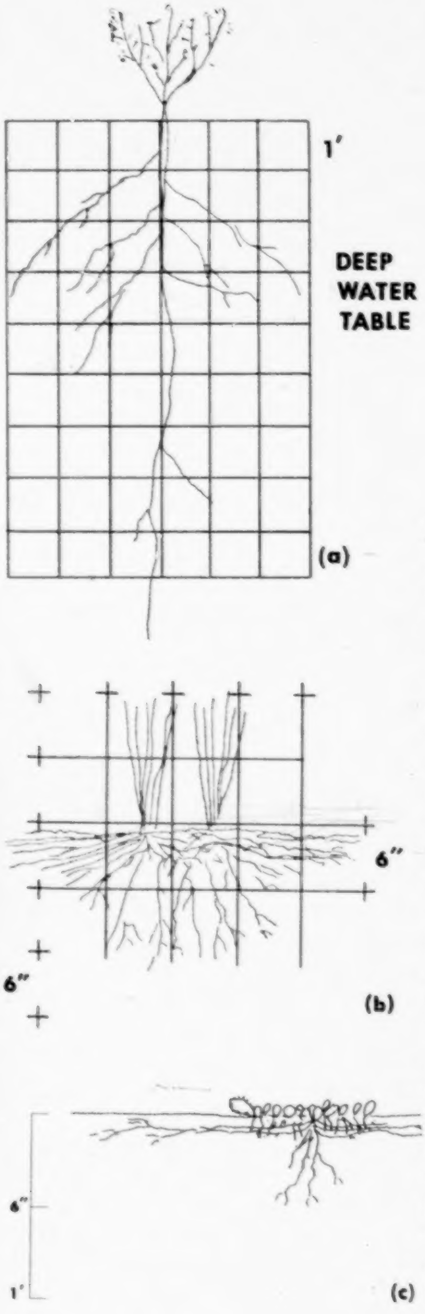
The activity of dunes eventually is lessened by pioneer plants which take root in their shifting sands. Marram grass, poverty grass, and other hardy plants become obstacles to the wind and hasten the growth of a dune as sand grains lose velocity and drop among their stems and blades. To survive, plants must keep pace with changing contours, or grow above the rising sand. Elongated stems result, and when the dune has finally passed by, the plants, if still erect, display awkward topknots of vegetation.

Beach heather (Hudsonia)*--one of the most successful pioneer dune plants—grows close to the sand and forms a miniature but effective windbreak, with the result that the sand level in the area rises into little hillocks.* Hudsonia *blooms in the spring, covering the dunes in yellow.*

Marram grass usually bends with the wind, but a weakened blade may break and scribe arcs in the sand as the wind blows.







The root systems of dune plants often are modified to exist in shifting, abrasive soil where the water table may be far below, or where water must be absorbed as it percolates rapidly downward after a rain. Marram grass with its long sub-surface runners is the most abundant, but lupine (a) reaches down nearly 10 feet; wiregrass (b) proliferates its root system just beneath the surface; and the prickly pear cactus (c and d, side and top views) extends itself widely through sandy soil.

A SAND dune is an environment hostile to many forms of life, yet it supports enough organisms, even aquatic protists, to make population studies feasible. Those organisms that are present are understandably suited to a life in a world of searing heat, abrasive grains, aridity, and little shelter. The adaptations of foliage and root systems of dune plants usually are quite clear. Animals, on the other hand, are less frequently seen. Primary consumers are rare, for there is not enough vegetation to support the usual large population of plant-eaters that constitutes the base of a food pyramid. Most of the animals are active predatory burrowers or fliers. Rabbits, mice, and maritime locusts are the primary herbivores, but predatory and scavenging insects, spiders, amphibians, reptiles, and birds are everywhere. Some food chains are almost completely closed, with only occasional contributions from the plant-eating population. For example, velvet ants prey upon digger wasp larvae, but velvet ants are parasitized by bee flies. Bee flies may be captured by robber flies, and both of these flies are picked up when weak or dead by digger wasps.

Before student groups are taken to a sandy area, it is well to determine as much about its history and present state of activity as possible. Some dunes, such as those of Indiana, Michigan, Maine, Massachusetts, Delaware, and Virginia, are mostly homogeneous masses of sand, each arising from a single origin. This homogeneity can be determined by a particle-size analysis using a graded series of sieves, similar to those currently available for the ESCP course. If all grains show little disparity, the dune may have had a determinable origin, both in place and time. A migrating dune, blown along, is the result of selective action by the wind. Large particles are left behind, and exceptionally fine ones are carried far away and dispersed. Later, as a dune becomes stabilized by vegetation, a wider range of particle sizes again becomes apparent.

Examination of grains themselves may reveal other features of importance to sand-dwelling organisms. An old dune which has migrated some distance will be composed of rounded grains, while dunes of more recent origin may have particles with sharper, more irregular shapes. The shape of sand grains determines not only abrasive quality, but surface area—both matters of some importance. (The sand I am referring to is the largely quartz sand of most shorelines, and not the highly irregular, crumbling, calcareous sand of semitropical regions, such as the Florida Keys.)

Abrasion can be a severe, but not prohibitive, limiting factor. At times it can destroy roots, but is even more dangerous to stems exposed to strong prevailing winds. The effects and direction of a prevailing wind can be found in the scars on one side of woody stems. These scars, the result of sand-blasting, can reach down into the cortex of a dune shrub or tree. Somewhat similar effects are caused by the dessication of tissues on the windward side and accelerated growth on the other, which results in gnarling and twisting. Of course, the more successful grasses and nonwoody plants simply bend with the wind and offer little resistance to flying sand grains.

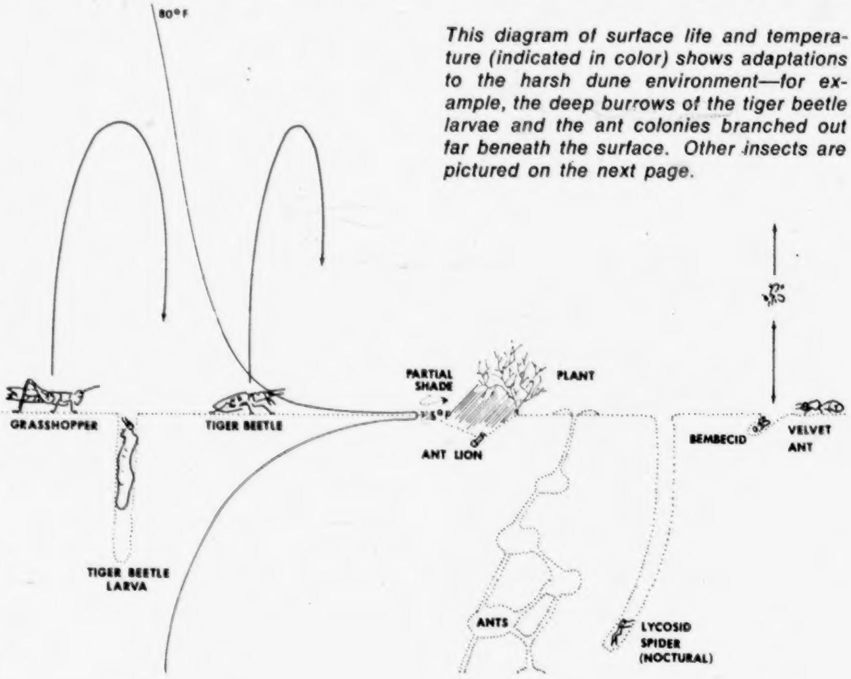
Grains of irregular shape, or lessened sphericity, offer large pore spaces and more surface for capillary water, although after a rain most water percolates down through the upper sand rapidly until the water table is reached. Many plants, even those living high on a dune, are obliged to send down long tap roots to the water table, perhaps three meters beneath the surface, where rootlets branch profusely.

Where capillary water persists near the surface, an unsuspected flora and fauna are to be found. It is surprising to students how much can be seen with a microscope in water collected from moist sand by means of simple tubes and perforated cores. Protists, nematodes, tardigrades, harpacticoid copepods, and other invertebrates are usually present. It is not difficult to concentrate them from the water collected by simple centrifugation. These organisms, especially nematodes and harpacticoids, provide fine opportunities for student evaluation of morphological adaptations. These motile, elongated creatures wriggle easily through pore spaces in a subsurface world of sand water that is far more extensive than one would suspect standing on a dry, shifting surface. If students determine the volume of capillary water by comparing wet and dry weights of sand samples, the extent of the sand-water environment becomes apparent. As much as one-fifth of the water falling on a dune may be held just beneath the surface in capillarity.

On a clear summer day the surface of a sand dune is almost devoid of animal life. Temperatures here can be high enough to coagulate blood proteins of unprotected, poikilothermous insects, and many of them possess structural or behavioral adaptations that minimize this danger.

On many dunes, the only insects found on the surface on hot, sunny days are velvet ants, which are really wingless wasps heavily insulated with a thick "fur." Dune spiders, many digger wasps, bee flies, and robber flies are also pilose, but the degree of their insulation does not equal that of the velvet ant. This formidable insect (it has a painful sting) runs rapidly across the sand in search of the burrows of the digger wasp, whose larvae it parasitizes with its own eggs and larvae. It is active up to temperatures of 122°F (50°C), but beyond this, it seeks shade.

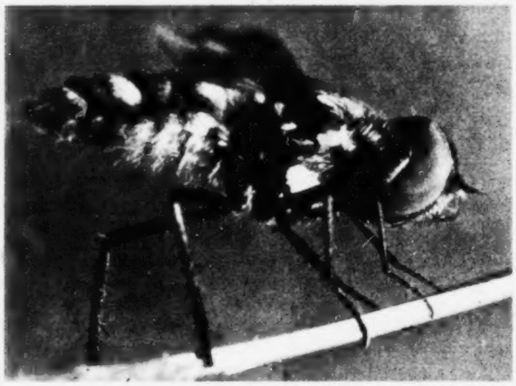
Subsurface temperatures drop rapidly, so an examination of the burrows of rabbits, mice, toads, digger wasps, wolf spiders, ants, and other creatures enables students to determine the favorable conditions a tunnel or burrow provides. A small evapometer or wet and dry bulb thermometer placed in an artificial burrow will show lessened rates of water loss, compared to



This diagram of surface life and temperature (indicated in color) shows adaptations to the harsh dune environment—for example, the deep burrows of the tiger beetle larvae and the ant colonies branched out far beneath the surface. Other insects are pictured on the next page.

The velvet ant is insulated against surface heat by its thick coat of hairs.

The digger wasp takes frequent vertical flights until its burrow extends into cooler strata of sand.



The bee fly seldom alights on the surface but prefers to cling to vegetation.

The tiger beetle takes short, cooling flights, as indicated on the diagram on page 17.

conditions on the surface. A cool, moist burrow is important to animals which otherwise might become dehydrated through the moist membranes of their lungs or tracheal systems. To measure the subsurface temperature gradient, one needs only to lower a thermometer down a narrow vertical tube sunk in the sand and left in place overnight. A remote reading thermistor-thermometer would be even better.

Temperatures taken in the air to a height of a meter or two will show a similar, but not so pronounced, gradient. Dune grasses rising into these cooler strata usually support a variety of insects on their blades, but the insects are not necessarily plant eaters. One primary consumer, the maritime locust, can be found clinging to blades of marram grass, but just as frequently alights on the sand surface at midday for brief periods until it takes cooling flights. When it is on the hot sand, as its own temperature rises, it begins to raise its body by straightening its legs until it is standing almost on tiptoe. Predatory tiger beetles flick into the scene, run rapidly across the sand, and then they too fly swiftly into the cooler air above the dunes.

Some insects, such as the digger wasps, utilize both subsurface and aerial gradients and spend only very brief intervals on the superheated surface. One of these bembecid wasps alternately hovers and digs until its burrow descends below the critical temperature. It then provisions the burrow with dead and dying insects and finally lays a few eggs.

Should students have difficulty in capturing dune insects, most of which are swift fliers or runners, they may wish to excavate sand wolf spiders from their easily identified, round, vertical burrows which are shored up by a tube of webbing. Wolf spiders can be found at the surface at night without difficulty because their eyes reflect a flashlight's beam with a bright, cold brilliance.

Some of the more passive insects live only in certain places in the dunes. The predatory larvae of tiger beetles, for example, hold their armored heads flush with the surface while wedged in vertical burrows excavated in the moist sand surrounding a dune pond, or where the water table comes close to the surface. At the bottom of the slipface, where the sand grains are finer than in any other region, students may discover the conical pits of ant lions. These ferocious larvae of a weak, ineffectual flying adult, capture any insects that fall into their traps, paralyze them, and then remove their tissues, which have been liquified by histolytic enzymes injected through the larvae's long, sickle-like jaws.

Even with an absence of animals on the dunes in the daytime, students can discover extensive evidence of their activity the preceding night. Each creature leaves a diagnostic track in the loose sand, whether it is a beetle, toad, snake, tortoise, or mouse. Some tracks are puzzling at first; with many it is possible to determine in which direction the animal was traveling, what it ate, and what may have happened to it. Tracks are soon blown over, but early in the day the surface of a dune clearly reveals the activities of its population.

Mice and rabbits might be flushed from shallow burrows under heavy crest vegetation on a dune that is being stabilized, but toads and snakes—the hognose for example—submerge beneath the sand during daylight hours, leaving no trace except for their telltale tracks of the night and early dawn. In the West, some snakes and lizards can be followed as they move under the sand by the surface ripples caused by their subsurface movements.

FOR PERSONS with more passive interests, dune plants form fascinating objects of study. Some have leaves covered by dense masses of hair-like trichomes, an insulation analogous to the pilosity of dune insects and spiders. Other plants have thick, waxy cuticles, or leaves that are heavy and scale-like and are held pressed tightly against the stem, lessening exposure.

Certain dune plants can be found holding their leaves vertically, so the broad portions of the blades are neither struck directly by the sun nor exposed to intense back-radiation from the sand. Such leaves usually have equalized internal structures with palisade layers on each side. Some dune plants fold their leaves at midday, while others flower and grow most actively early or late in the season or only following rainstorms. The western white primrose, for example, loses its leaves during times of drought, only to grow new ones quickly following a rain.

A close study of leaves often reveals interesting modifications. Stomates may be reduced in number, lessening the rate of transpiration. Another modification can be found in the cacti, whose leaves are modified as spines and which carry on carbohydrate production in their green, flattened stems. Without functional leaves, water loss is minimized, and the precious fluid can be stored. Cacti are remarkably hardy along the perimeters of sandy areas, and are able to continue active growth in temperatures as high as 136°F (58°C).

THE whole subject of pigmentation offers much to investigate. Many dune creatures, both vertebrate and invertebrate, are light colored, lacking the brownish pigment, melanin, which darkens their woodland relatives. Melanin is formed most abundantly at comparatively low temperatures and is suppressed in hot environments, a fact that has been demonstrated in a number of insects and the well-known Himalayan rabbit. Other factors are known to influence darkening or paleness: Moisture causes some locusts to darken, while dryness has the opposite effect. Does this explain the sand-colored maritime locust? Some dune insects are pale regardless of conditions of the physical environment. Natural selection by predators who are quick to spot color contrasts against the sand undoubtedly plays a role, but many dune animals are light colored despite the fact they are exclusively nocturnal. How are they favored by being light in color? Perhaps the only conclusion possible is that the prevalent conditions met on dunes—heat and aridity—are known to produce paleness, which in turn provides some measure of protection from predators, however slight.

WITH only simple equipment and a little ingenuity, science students can measure the progress of a dune, estimate its origin, define its physical parameters, examine highly specialized organisms, unravel population interactions, and find evidence of biotic succession. None of this is so easily done in other habitats. Those schools fortunate enough to be within reach of sand dunes may discover they have a useful and important adjunct to their academic programs. Earth science classes, for example, are able to use a dune area almost at once, and repeatedly through the year. A physics class might be stimulated to study the dynamics of dune movement and the various physical phenomena of dune formation: wind velocity and particle transport, wind shadows, turbulence, laminar flow, friction, the angle of repose, and so on. Biology classes will discover much to arouse interest beyond the few topics touched upon here. Each dune has its characteristic populations and dominant species, its pioneers, interactions among species, and modifications of form and activity.

Having introduced many students and teachers to the Atlantic dunes, I am convinced that these lands hold meaning, fascination, and genuine pleasure for the student investigator.

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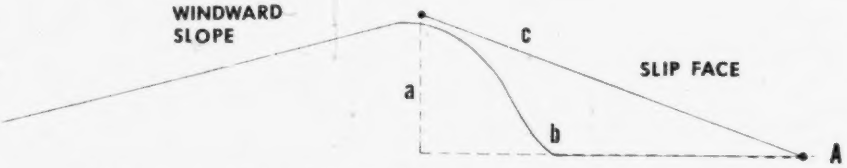
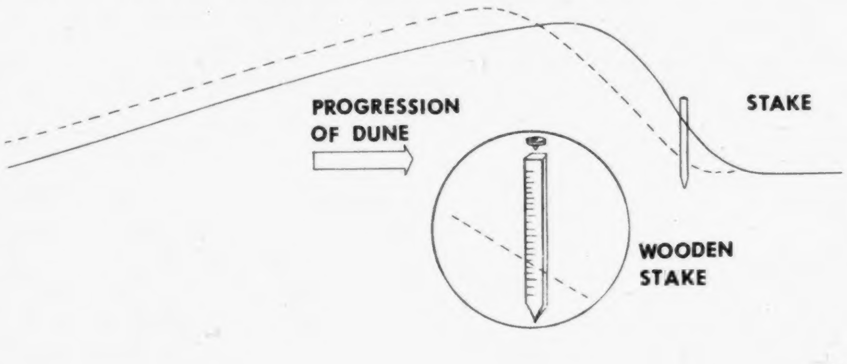
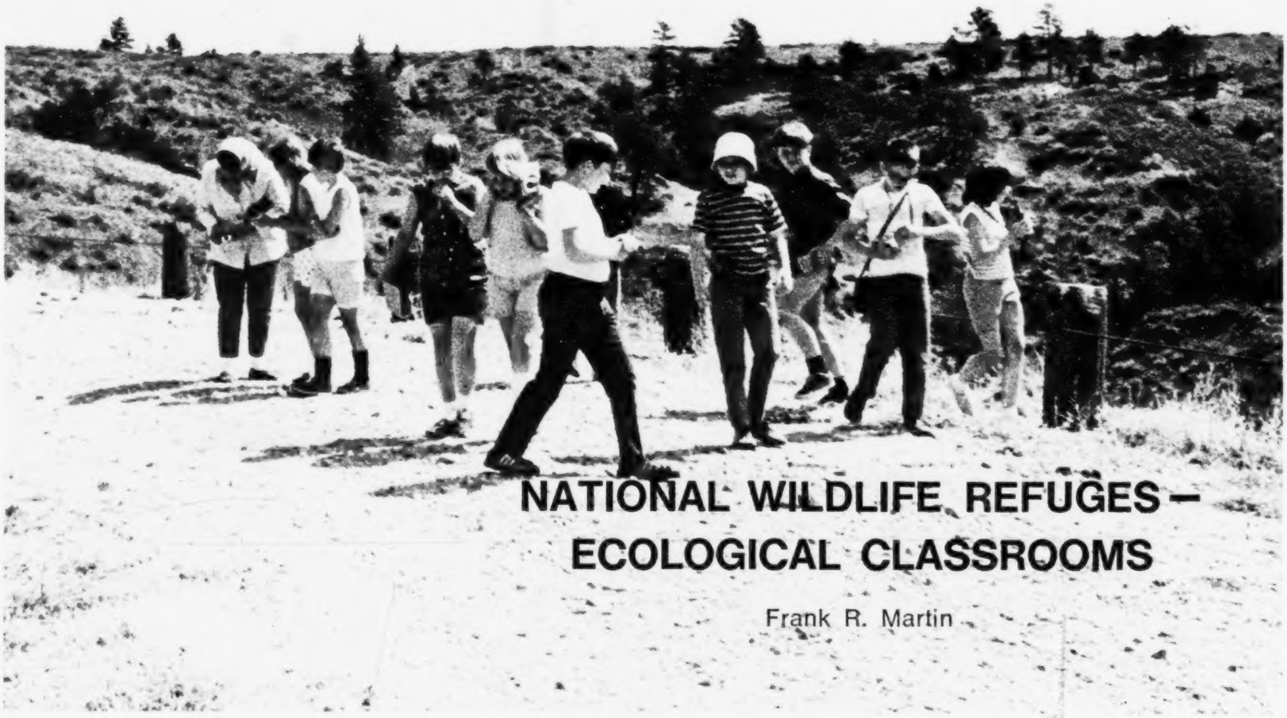


Although a hypsometer, which gives a direct reading, is the most useful instrument for measuring the height of a dune, triangulation (above) can be used. First, a measured string is attached to the crest and brought forward to ground level. Then, using a protractor with a level, a sextant, or a transit, angle A is determined. A right triangle is assumed, line a being vertical and line b horizontal. The height of line a is determined by using a Table of Natural Functions and the formula a = c • sin A. The rate of progression of a dune (below) is measured by using graduated, numbered stakes pounded into the soil at the bottom of the slipface. The angle of the slipface can be measured with a clinometer (protractor with plumb line) or estimated at 34°. The horizontal migration can be calculated from the rise of the sand level around the stake over a period of time; it is about 75 percent of vertical rise.





NATIONAL WILDLIFE REFUGES – ECOLOGICAL CLASSROOMS

Frank R. Martin

"THIS is tremendous," the young biology teacher exclaimed as the last of her class looked out on the pond through the spotting scope. Twenty-one students had been taking turns watching a Canada goose on a nest atop a muskrat house. Standing nearby, the manager of the National Wildlife Refuge was answering questions and occasionally adjusting the scope to keep "on target." The teacher had reason to be elated. This was her first trip to one of the federal wildlife refuges, and it was less than ten miles from the school where she taught. She knew she'd be back with her class again since there were many points of interest they had not seen on the one-hour tour. The refuge manager, too, knew they would be back. He realized from past experience that the teacher would inform other teachers, and the students would undoubtedly be back with friends or their parents.

Over 300 refuges totaling 30 million acres are widely distributed in 46 of the 50 states. About 180 have trained wildlife managers "on the ground." Many of the unstaffed areas, such as waterfowl-production areas in the prairie states, can be visited on a conducted-tour basis by contacting the manager of the nearest large refuge. Visitors are always welcome, and public use is restricted only when in conflict with the primary wildlife management programs.

The author is manager of the Charles M. Russell National Wildlife Range, a 920,000 acre unit of the National Wildlife Refuge System, Lewistown, Montana.

Although national wildlife refuges were established originally for migratory waterfowl, many refuges now benefit other kinds of wildlife. For example, the Desert Wildlife Range in Nevada provides habitat and protection for the desert bighorn sheep. Particular attention is being given to environmental preservation, and studies of wilderness candidate areas are being conducted on many refuges and wildlife ranges under provisions of the Wilderness Act of 1964.

A priority goal of the National Wildlife Refuge System is to assure the survival in a natural state of each of the nation's plant and animal species. A number of the refuges provide habitats for rare and endangered species. The Aransas refuge in Texas is famous for its whooping crane wintering grounds, and the Hawaiian Islands National Wildlife Refuge supports the entire population of four of the nation's fifty endangered birds.

A visit to a wildlife refuge is more than just a bird watching trip. The teacher can give students a variety of learning experiences through the great diversity of flora and fauna. In preparation for a visit, the manager in charge of the area should be contacted by the teacher and certain information obtained. The trip can be more meaningful at some seasons than at others. Publications dealing with the area should also be reviewed. Refuge leaflets, bird lists, and, in some cases, mammal and reptile lists are available. It is also advisable to tell the refuge manager how many people will be making the trip and whether or not a bus or automobiles will be used for transportation. Managers need advance notice: one week is usually sufficient. In written requests, teachers should give a telephone number indicating where the person in charge of the students can be reached.

National Wildlife Refuges and Waterfowl Production Areas are ecological gems and provide places where biology teachers can instill an environmental consciousness in young Americans. In some parts of the country where units of the national wildlife refuges are close to huge population centers, they are the only remaining truly natural areas. Teachers wanting to take advantage of these areas should write for a refuge managers list and a leaflet, *The National Wildlife Refuge System,* available from Bureau of Sport Fisheries and Wildlife, U. S. Department of the Interior, Washington, D.C. 20240. □

AN EXERCISE IN WINTER ECOLOGY

Brother James Murphy, CFC

THE below-freezing temperatures that characterize winter in many areas cause the flora and fauna of these environments to alter their life styles quite drastically. Winter exercises which we use with our students are designed to show how living things survive during one of nature's most trying periods. A prairie or open field is the best location for the exercises, but any outdoor area, even a city park, is satisfactory—provided some animal life is present. If possible, schedule the exercise so that it can be conducted a day or so after a snowfall when there will be clear, fresh animal tracks. The equipment required is a pocket knife and a large plastic bag for collecting materials in the field. Students should be told to come dressed for work outdoors. Beyond that, we give the students several sheets of questions as a guide to the activities, and they go ahead on their own.

Most of the following exercises are self-explanatory, but the suggested rabbit chase does merit some explanation. Catching a rabbit may seem improbable, but it is possible to catch a cottontail if you know a little about the animal and have some faith in the physical capabilities of your students. The rabbit as a species has been able to survive by sheer numbers, protective coloration, and the ability to maneuver at high speeds. The animal's Achilles heel is its lack of endurance. Once a rabbit has been scared out of hiding, all that is necessary to catch it is to keep it moving for about two to four minutes. Even a short rest, and the chase time must start all over again. If the rabbit is not given a chance to rest, it will collapse of exhaustion. It can then be picked up by the scruff of the neck with one hand and a good grip on the hind legs with the other hand. The rabbits can be placed in a burlap bag for easy handling. After they have been measured, weighed, sexed, and tagged for future identification, they should be released in the area where they were caught. If the animals are detained, especially indoors, for more than a few hours they will rapidly lose the vigor that is so necessary for survival in cold weather.

Following are typical handout sheets for the students:

During the winter months the overall life activity of plants and animals in the northern part of this country goes into low gear. Only a few organisms maintain an active daily schedule for survival; most organisms reduce their metabolism to a bare minimum.

The first activity in the field is to investigate the forms of animal life that are active at this time. The easiest way to do this is to find and identify animal tracks in fresh snow. In studying the tracks, take care not to destroy them. Tracks should be left so that other students may see them. Other evidence of animal life can be found in tree hollows, under logs, and in debris. Return all objects to their original position, so they may continue to serve as a possible source of shelter for animals.

Also note which birds are in the area. Make a list of the animals that are active at this time of year. Compare this list to records of the animals that are found in the area during the summer, and note the organisms that are missing. What similarity exists among the animals found during the winter? List any similarities among the animals found only during the summer. Try to explain the whereabouts of several animals that are not present during the winter. If you scare up a living rabbit, give chase. How close were you to the animal before it moved? Can you explain its reaction? If you chase the animal, it will consider you to be a predator. What does the rabbit do to avoid being caught? If you are able to keep the rabbit moving, it will tire within two to four minutes and can easily be caught without harming it. An interesting study can be done with rabbits that are caught, if they are tagged and released. More complete details on this can be found in several of the books in the reference list.

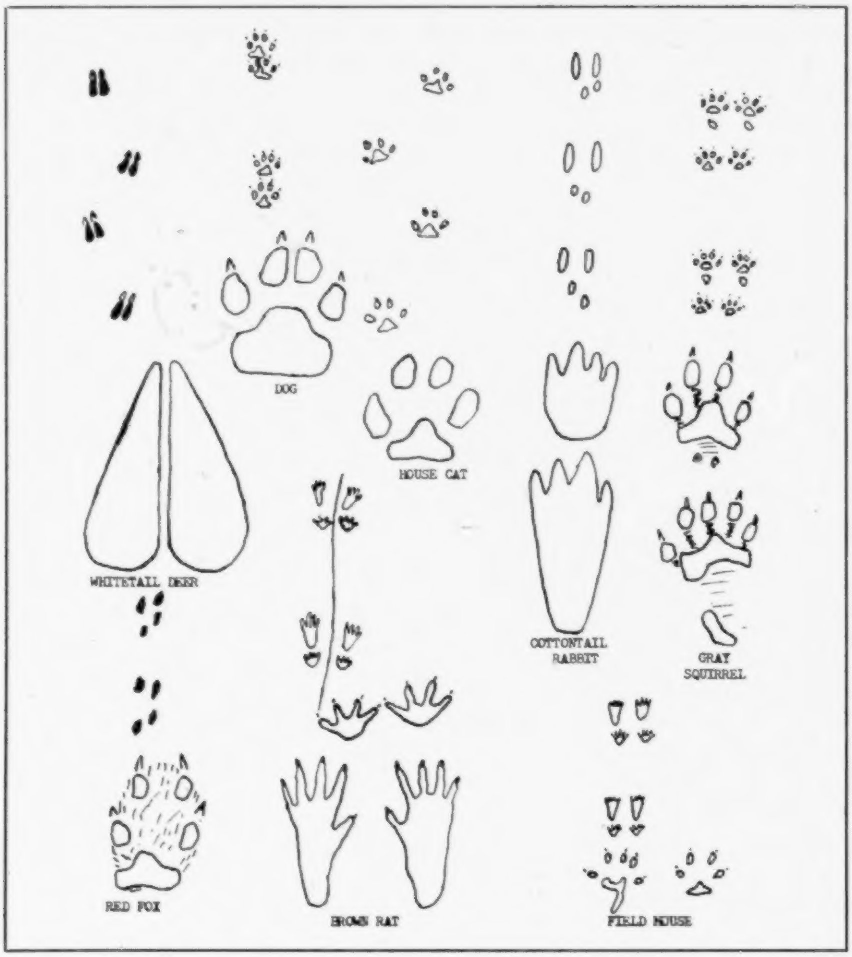
Find the tracks of an animal and follow them for about ten minutes. Did the animal follow a path or just cut across the terrain at random? Did the animal stop during its movement; if so, why? After following the tracks for some time

Brother Murphy is science department chairman, Brother Rice High School, Chicago, Illinois.

This double header resulted from one rabbit running into another. Both animals are exhausted, but both are unhurt.

An exhausted rabbit is held by the scruff of the neck and the hind legs as it is deposited in a burlap bag for transporting.

A rabbit remains quiet in the burlap bag and is easily weighted. Many rabbits surpass the average life span of one year.



The animal tracks pictured above are some of the most common found during the winter. The small sets of imprints shown above the larger drawings are meant to give some idea of the animal tracks. If the front and hind foot of an animal are very different, the front foot is pictured above the hind one.

do you have any information on the animal's source of food and where it finds shelter?

Hibernating insects and spiders of various types may be found under a loose piece of bark or in debris. Insect larvae may be uncovered if you slit down the frozen stalks of some herbs, such as sunflower plants. Larvae may also be found in cocoons attached to plants. What is the source of food for these organisms, and how do they keep from freezing during the winter? You may see abnormal swellings in various parts of plants. Probably these are plant galls. They can be found on a large number of different plants. Make a list of the galls that you find: Record the type of plant, plant part that is affected, and, if possible, determine the name of the animal causing the growth. Use a sharp knife to make a cut in a gall, just off center. If you find a living organism inside, describe it. If the gall is empty, try to figure out what happened to the organism that was inside. Are the animals that cause a gall parasites? An interesting long-range project is to place galls or cocoons in a covered jar and store it in a moderately warm and humid location. Under these conditions you will be able to see the insects emerge from their hibernation.

Observe the plants in the area. Identify any that are green, and try to explain how this is possible. Break several small branches on a tree. Are they frozen? If not, why? Examine the buds at the end of a branch. How are they protected

Nontoxic spray paint is applied to the animal's tail, with a color code for sex and area distribution. It provides information on the animal's movements.

Small numbered tags are placed in the animal's ear. If care is taken to avoid blood vessels, not a drop of blood will be shed. The tags aid in gathering data.

The rabbit's length from nose to tail is recorded as part of that animal's life history. Then the rabbit is released at the site at which it was captured originally.

from the cold? See if you can find some small green plants close to the ground. These are usually biennials such as wild lettuce, thistle, and mullein. How does the structure of these plants protect them from the cold and from animals in the area? Examine the lower bark of trees and shrubs; are they being eaten? Why would extensive damage to the bark cause death to these plants? Construct a food web for the area that you are studying. If you have made a food web for the same area during the summer, compare the two and note differences. ☐

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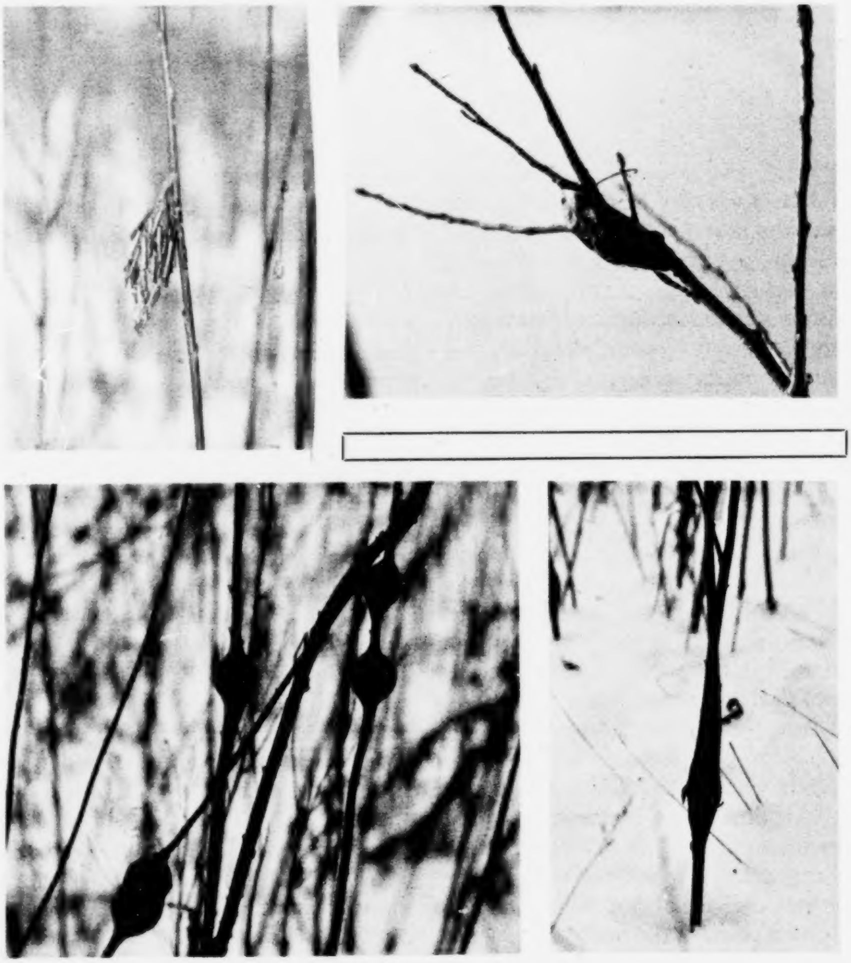


Plants provide winter homes for some animals. Pictured above, left to right, are a butterfly cocoon and a moth cocoon. Bottom, left to right, are a round gall in a goldenrod stem caused by a fly and an oval gall caused by a gall moth.

Weather and Climate Research

JULIAN KANE

Science Teacher
Garden City Senior High School
Garden City, New York, and
Senior Lecturer
Hofstra University
Hempstead, New York

and

MICHAEL ADAMS, JOANNE ARENA, CYNTHIA BAKER, JOSEPH BILLMEIER, GERALD CARUCCI, ARMAND CHAGOLL, SALLIE CHARLES, FRANK COUGHLIN, ROBERT DELAHUNT, ROBERT HAZEL, GERARD LAURO, JOANNE McENTEE, DOUGLAS McEVOY, DOROTHEA SCHIPP, JEAN SEWELL.

Students at Garden City Senior High School

RESEARCH courses conducted at Garden City Senior High School over the past few years have enabled students to work individually or jointly on projects in the earth, space, atmospheric, and environmental sciences. Approximately 40 youngsters each year (mostly twelfth-graders) sign up for one of the research courses after taking an elementary earth or space science course. Although our research projects range from estuarine microorganisms to the planets, this paper deals solely with our activities in the atmospheric areas.

Occasionally, our projects are supported by corporate and foundation grants, and we have been fortunate enough to have had several articles published in journals such as *Nature, Science,* and *The Science Teacher*. Many of our projects involve joint student-teacher research; while others include little or no participation on the teacher's part. When a research team is organized to work on a particular project, each member is made responsible for a phase of the work. Each phase (planning, investigation, interpretation, and report writing) usually has a different student leader who is responsible for that operation. If the teacher is actively participating in the project, he serves as overall coordinator, consultant, and coinvestigator.

The students themselves decide which projects they wish to work on—and when and how they do the work. Although we meet daily in the classroom, much of the research is carried out during free periods, after school, weekends, and holidays. Periodic reports and seminars keep all members of the research group aware of progress and problems on the various projects.

Two of the students have received NASA-NSTA awards for their work in the atmospheric sciences: Janet Botte in 1969 for research on the effect of meteor particles on world precipitation patterns, and Dorothea Schipp in 1970 for research on particulate air pollution in Garden City.

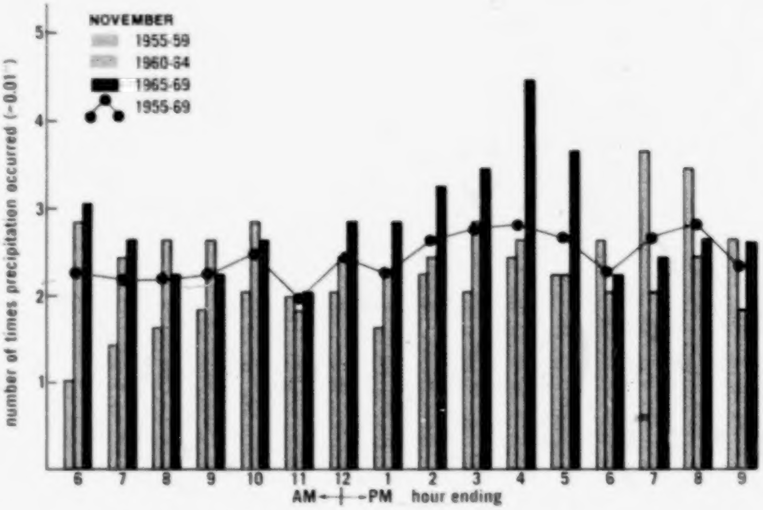
A summary of eight of the weather and climate research projects is given below. Each project, except the eighth, was supported by a research grant. The eighth appeared in *TST* (Feb. 1969).

1. *Hourly Precipitation Frequencies for each Month at Central Park, N.Y., from 1955 to 1969* by Julian Kane, Jean Sewell, Michael Adams, Armand Chagoll, Frank Coughlin (May 1971).

Using weather data obtained from the Environmental Science Services Administration, we determined how often 0.01 inch or more of precipitation occurred for each of 16 hours at Central Park in New York City over a 15-year period (1955 to 1969). The hours included those ending at 6 AM to those ending at 9 PM. Major findings (based primarily on analyses of the last five-year segment: 1965-69) were:

a. Precipitation occurred more frequently (but in lesser amounts) during the 1960-64 drought period than during the preceding and following five-year periods when fairly normal precipitation amounts fell.
b. The hours of greatest precipitation frequency were those ending at 6 AM, 2 PM, and 3 PM. The hours of least precipitation frequency were those ending at 9 AM, 10 AM, and 11 AM.
c. Hourly precipitation frequencies were generally higher from Novem-

Figure 1. November hourly precipitation frequency for each of three 5-year periods and for total 15-year period (1955-69). Central Park, New York City.



ber to April, and generally lower from June to October.

d. In November, December, and January, most of the high precipitation frequency hours were in the afternoon. In February, March, and April, most of the high precipitation frequency hours were in the morning.

e. In May and October, most of the low precipitation frequency hours were in the afternoon. In June, July, and September, most of the low precipitation frequency hours were in the morning.

f. December had the highest precipitation frequency (10 percent), August had the lowest (4.3 percent), and May had the most normal precipitation frequency for the 16-hour segment of the five-year period (7 percent).

The 1960-1964 drought period had 2,023 precipitation hours compared with 1,975 precipitation hours for the 1955-59 period and 1,980 precipitation hours for the 1965-69 period. Apparently, precipitation occurred more frequently during the drought period, but in significantly smaller amounts.

Tables 1 and 2 and Figure 1 present some of the data from this study.

2. *Particulate Air Pollution Survey of Garden City, N.Y., October 1968 to April 1969* by Julian Kane, Dorothea Schipp, Joseph Billmeier, Gerard Lauro (December 1969).

Using equipment installed on our high school roof and controlled from our classroom, we operated a Hi-Vac Air Sampler over a six-month period according to the standard six-day 24-hour schedule set by the New York State Department of Health. The Nassau County Department of Air Pollution Control showed us how to install, operate, and maintain the equipment and how to gather the data. Major findings of this project were:

a. Garden City had less particulate pollution than many other areas

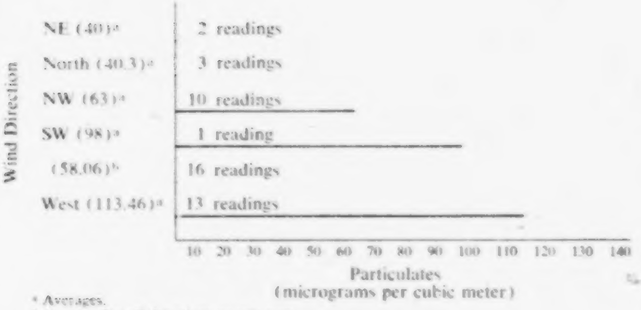
Table 1. Hourly precipitation frequency averages for 1965-69 (> 0.01"), Central Park, New York City.

(−) ≤ 1.5 TIMES/MONTH PRECIPITATION OCCURRED (< 5%)
(•) = 1.5-2.9 TIMES/MONTH PRECIPITATION OCCURRED (5% to 10%)
(+) ≥ 2.9 TIMES/MONTH PRECIPITATION OCCURRED (≥ 10%)

		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	(Totals) —	•	+
AM	6	•	•	+	+	•	—	•	•	•	•	+	+	1	7	4
	7	•	•	+	+	•	—	—	—	•	•	•	•	3	7	2
	8	•	•	•	+	•	—	•	—	•	•	•	+	2	8	2
	9	•	+	•	•	•	—	—	—	—	—	•	+	5	5	2
	10	•	+	•	•	•	—	—	—	—	—	•	•	5	6	1
	11	•	•	•	•	•	—	—	—	—	—	•	•	5	7	0
	12	•	•	•	•	•	—	—	—	•	—	•	•	4	8	0
PM	1	+	•	•	•	—	•	—	—	•	—	•	+	4	6	2
	2	+	•	•	•	•	•	—	—	•	—	+	+	3	6	3
	3	+	•	•	—	•	•	•	—	•	—	+	+	3	6	3
	4	•	•	•	—	•	—	—	—	•	•	+	•	4	7	1
	5	+	•	•	•	•	—	•	—	•	—	+	•	3	7	2
	6	•	•	•	•	•	—	•	—	•	—	•	•	3	9	0
	7	•	•	•	•	•	•	•	•	•	•	•	•	0	12	0
	8	•	•	•	•	•	•	•	•	—	•	•	+	1	10	1
	9	•	•	•	+	•	•	•	•	•	•	•	•	0	11	1
Totals	—	0	0	0	2	1	10	8	12	4	9	0	0	46		
	•	12	14	14	10	15	6	8	4	12	7	11	9		122	
	+	4	2	2	4	0	0	0	0	0	0	5	7			24

Table 2. Monthly precipitation frequency totals for three 5-year periods, Central Park, New York City. (For 16-hour period. Hours ending 6 AM to 9 PM.)

	1955-59	1960-64	1965-69	1965-69
MONTH	TOTAL	TOTAL	TOTAL	AVERAGE
January	146	194	200	2.5
February	183	233	178	2.2
March	282	216	202	2.5
April	228	214	181	2.3
May	115	111	168	2.1
June	117	122	108	1.5
July	92	138	133	1.7
August	131	110	98	1.3
September	94	162	140	1.8
October	207	106	112	1.4
November	172	189	223	2.8
December	208	228	237	3.0
Total	1,975	2,023	1,980	2.1



[a] Averages.
[b] Average for all directions except west.

Figure 2. Particulate pollution levels in Garden City, New York, compared with prevailing wind directions. (October 1968 to April 1969)

in Nassau County. (Comparisons were made with nine other areas in the County.)

b. Pollution levels were highest in Garden City when the wind blew from the west—where the New York metropolis is located.

c. Pollution levels were lowest on Sundays and highest on Wednesdays.

d. Pollution levels were significantly lower on days when precipitation occurred than on days when no precipitation fell.

e. None of 10 Nassau County air-sampling stations surveyed showed pollution levels which conformed to the standards set by the New York State Department of Health. Garden City, however, came closest to meeting the state's minimal particulate pollution standards.

Figure 2 shows the pollution averages for different wind directions.

3. *Average Maximum Temperature Variations: (1950 to 1969) for Central Park, N.Y.*, by Robert Hazel and Jean Sewell (December 1970).

Working primarily during after-school hours, the students used an Adelphi University computer to analyze monthly and seasonal temperature maximum changes over a 20-year period in New York City. Their major findings were:

a. The annual average temperature maximum declined from 63.0°F in the 1950-54 segment to 61.9°F in the 1965-69 segment.

b. Seven months (January, February, July, September, October, November, December) showed temperature maximum declines during the 20-year period. The other five months showed temperature maximum increases.

c. The "cold" season (November to March; when the average maximums were under 60°F) showed the greatest decline.

The data were summarized in four 5-year segments to show trends for each month and also in "seasonal" segments as shown in Table 3 to determine general trends.

Table 3. New York Central Park average maximum temperature in degrees Fahrenheit ("seasonal" trends).

	1950-54	1955-59	1960-64	1965-69
"Cold" months November-March	46.4	43.8	44.0	41.3
"Winter" months January-March	44.8	41.4	42.0	41.3
"Spring" months April-June	70.3	70.5	71.4	71.1
"Summer" months July-September	81.8	81.7	81.0	81.8
"Fall" months October-December	55.0	53.4	53.8	53.1
January-June	57.6	56.0	56.7	56.2
July-December	68.4	67.6	67.4	67.6
Twelve-month average	63.0	61.8	62.1	61.9

4. *Temperature Variations in the New York City Urban Area Compared with two Rural Communities (Canton and Lake Placid, N.Y.) over a 20-year Period*, by Robert Hazel (February 1971).

Temperature trends over a 20-year period in New York City and in two Adirondack villages were compared via a computer study to determine possible urban effects on climate. All trends noted except for the first one can be explained by the urban region's large winter fuel consumption per unit area as compared with that of the rural regions. Some of the findings for the 20-year period (1950 to 1969) based on half-decade analysis were:

a. The coldest months, January and February, experienced the greatest mean temperature decreases in both urban and rural areas.

b. All three areas experienced mean temperature decreases, but the urban area showed a smaller decrease than did the rural ones.

c. The February rural minimum temperature decrease was approximately double that of the urban one.

d. The February rural maximum temperature decrease was about equal to that of the urban one.

e. The February rural mean temperature decrease was approximately 1.5 times that of the urban one.

f. The February rural temperature range (difference between high and low) increased about 3.0°F, while the urban range decreased 0.5°F.

5. *Syzygy not a Factor in Langmuir Theory*, by Julian Kane, Gerard Lauro, Douglas McEvoy, Gerald Carucci (September 1969).

When Irving Langmuir and his associates conducted the world's first cloud-seeding experiments in New Mexico in 1949-50, Langmuir noted a corresponding general increase in precipitation in the eastern United States (as well as a specific increase in precipitation in New Mexico). His subsequent attempts to prove a cause-and-effect relationship met with much disapproval among meteorologists.

Before commencing a 21-year study of precipitation in New Mexico and New York to determine the validity of Langmuir's general theory that New Mexico weather patterns show up in the East four to five days later, we analyzed Langmuir's 1949-50 data to find whether syzygy had any influence in the patterns. In the time since Langmuir's work, it was discovered that the third, fourth, and fifth days after a syzygy (new or full moon) were generally the highest precipitation-potential days of a semilunar period (14 days). Our syzygy survey of the 1949-50 period showed that the lunar alignment played no role in Langmuir's precipitation patterns.

6. *Precipitation Forecasting via Langmuir's Cyclogenesis Theory,* by Julian Kane, Gerard Lauro, Joanne McEntee, Joanne Arena, Sallie Charles, Robert Delahunt, Cynthia Baker (May 1970).

In order to check Langmuir's theory that New Mexico's weather patterns could be used to predict weather four to five days later in the eastern United States, we analyzed precipitation records for Socorro, New Mexico, and for New York City over a 21-year period (1948 to 1968). We found that 34.9 percent of the times that precipitation occurred at Socorro, precipitation occurred in New York four or five days later.

The predictability percentage was not constant, however—varying from a low of 21.4 percent in 1950 to a high of 53.6 percent in 1953 and 1959. This meant that additional research was necessary to determine whether the Langmuir theory was correct or whether the correlation was merely due to the normal westerly weather trend in the United States. Table 4 shows the monthly correlation.

Table 4. Socorro-New York precipitation correlation (monthly) 1948-1968.

	PREDICTABILITY RATIO	PERCENT
January	14:57	24.5
February	21:49	42.8
March	21:53	39.6
April	20:45	44.4
May	18:45	40.0
June	11:57	19.8
July	47:181	25.9
August	61:171	35.5
September	38:100	38.0
October	25:65	38.4
November	14:32	43.7
December	23:41	56.0

7. *Langmuir Precipitation Forecasting Theory: No Validation Found,* by Julian Kane, Frank Coughlin, Michael Adams, Armand Chagoll, William Meisinger, Jean Sewell (March 1971).

This third and final project concerning the Langmuir Theory compared the precipitation patterns of New York City over a 10-year period (1959 to 1968) with those of Presidio, Texas; Fort Benton, Montana; and Socorro, New Mexico. The Texas and Montana regions were selected because they are the same radial distance from New York as is Socorro and have generally similar arid precipitation conditions.

The Langmuir theory that New Mexico precipitation could be used to predict weather patterns in the eastern United States did not hold up according to our analysis. Although Presidio, Texas, showed only a 14.1 percent correlation with New York City in precipitation, Fort Benton, Montana, showed a 33.3 percent correlation with New York. This latter percentage was slightly higher than the Socorro-New York correlation of 33 percent and indicates that New Mexico is not unique as a forecasting region for New York.

8. *Do Meteors Influence Precipitation?* by Julian Kane, Janet Botte, Victoria Bressan, Michele Barrett, Ann Sewell (February 1969).

A study of world precipitation patterns associated with the Great Leonid Meteor Shower of November 1966 showed a sharp increase during December 1966 as compared with 30-year averages for the more than 950 weather stations surveyed. According to a theory by E. G. Bowen, meteor shower particles drift down from the ionosphere to the troposphere in approximately four weeks, and then act as condensation nuclei for water vapor to enhance precipitation patterns on a worldwide basis. The December 1966 precipitation would have, according to the theory, been much greater than usual and also greater than the November 1966 or the January 1967 precipitation. Our analysis of "World Meteorological Organization Monthly Climatic Data" showed that the November and January world precipitation amounts were about 3 percent higher than their respective 30-year averages, and that the December amount was 11 percent higher. This indicates a positive correlation between the Leonid Meteor Shower of November 1966 and the increased precipitation of December 1966. Our research, therefore, confirmed the Bowen Theory.

ONCE students have mastered the rudiments of weather and climate in an elementary high school course, they are ready and able to undertake research work of a meaningful and useful nature. If the teacher keeps up with the latest theories and problems described in current journals, ideas for interesting high school research projects are not difficult to come by. In doing work of this nature, the students learn a great deal about the subject of their project as well as about the problems of handling research in general. The idea of being engaged in an original piece of research which might conceivably contribute something of value to the general body of scientific knowledge stimulates a degree of learning and working far beyond ordinary classroom activities. This last, of course, applies to the teacher equally as well as to the students. ☐

ACKNOWLEDGMENTS: The authors thank Good Weather, Inc., for grants supporting research studies 1, 3-7; William Meisinger for his help in working on the data for study 7; the William and Sophia Casey Foundation for support of portions of the research for study 2; and Judith Garelick, William Viet, and Joseph Lappano of the Nassau County Air Pollution Division for consultation throughout study 2.

ENVIRONMENTAL STUDY IN THE CITY

J. Rosson Overcash

TODAY, over 70 percent of our population lives crowded together on less than 4 percent of our land area. Simply put, we live in cities, and the urbanization of fringe areas around and between our major population centers is rapidly increasing. For large numbers of urban children the first robin has never been a sure sign of spring. "Rolling meadows and babbling brooks," "the murmuring pines and the hemlocks"—these phrases neither identify a pleasant scene nor evoke thoughtful memory in children whose outdoor experience has been limited to traffic and flashing signs.

Whether we may wish for it or not, the pastoral community of early-20th-Century United States is a thing of the past. Skipping rocks on a pond, collecting wild fruit and nuts, sliding down strawstacks—these common events of my childhood are not readily available to my own children. I make no value judgments here between my experiences and theirs; but it is important to note that there is a difference. The out-of-doors environment that was natural for me is not the out-of-doors environment that is natural for my children, or natural for most children today.

If today's urban youngster is to develop an ecological consciousness it must be developed in the setting where he is. To take him, once or twice, to a nature center will not suffice—valuable though the experience may be. What most of us understand as "the world of nature" is too remote, too seldom experienced, to be relevant to the inner-city student. There is, however, a "world of nature" in the city; and with only moderate effort the teacher can begin the development of an environmental ethic in the urban student.

To illustrate what might be done I have chosen an elementary school located in the North End section of Boston, Massachusetts. This is one of the oldest sections of the city. Old North Church is just around the corner, and Paul Revere's house is within a 10-minute walk. Narrow streets, crowded buildings, and apartments located over first-floor business establishments characterize the area. The school, a brick and stone structure with an asphalt play yard, is typical of many inner-city schools. Not an exciting outdoor environment at first glance; but there is an out-of-doors, and there is an environment.

THE building itself provides a starting point. A dated cornerstone reveals how long the building has been exposed to the atmosphere.

What changes have taken place during the past 40 or more years?
Is mortar beginning to crumble?
Does stonework show stains?
Have once sharp angles on stone or carvings become rounded?

Changes due to weathering may be more readily detected here than on a boulder exposed in a more natural setting. Here, too, one can see the effects of different climates, because the weathering may be more pronounced in a shaded, damp corner than in other areas. That same shaded corner may reveal other things as well. Here, in an area seldom reached by the sun, a bit of moss is growing.

Why is it here?
How did it get here?
Where did the soil come from?

This is an ideal situation in which to discuss the tenacity of living things. Not only must certain conditions be

The author is chairman of the Department of Earth Sciences, Northeastern University, Boston, Massachusetts.

met for each kind of living thing, but where these conditions are met, the living thing is likely to be found.

The asphalt play yard provides still further opportunities for discussing the out-of-doors. A temporary lake following a rain opens all the possibilities of slope, drainage, and erosion. Of equal significance, it opens a possible discussion on what man does to remove rainwater and snow melt from the city. With the ground surface of most cities 90 percent sealed by buildings, concrete, and asphalt, man has devised his own waterways to carry away running water. The gutter in front of the school can be incorporated into a lesson on running water. Sand and gravel collecting upstream from obstructions illustrate deposition. Debris being carried along shows the ability of water to transport.

WHAT living things are present here? Both plants and animals are available. Not in the profusion that might be found in a more suburban or rural setting, but there will also not be the distractions. Just across the street is a mini-park occupying a former building site. It contains only a few locust trees and some benches, but it provides an oasis of shade and some quiet for the residents. Here is a perfect opportunity for a class to "adopt" a tree.

Note the pattern of the bark.
Observe how the branches form.
What is the appearance of the leaves? Are they all alike?
In the spring this tree will bloom. What do the blossoms look like?
What insects visit the blossoms?

As the blossoms die and seeds appear, still more avenues for exploration are opened.

How many seeds are formed?
What chance do they have to grow?

Fortunately, pupils at this school are not limited to just one or one kind of tree. Only a block away is the Copps Hill Burying Ground which dates from the Revolutionary period. Here we find linden, horse chestnut, and American elm. Different bark, different seeds, different leaves; all provide an opportunity to discuss the variety of life. In the spring, flowers vary from the stately candles of the horse chestnut to the small, rarely noticed bloom of the elm. Few of our broad-leaved trees of the city are more fragrant than the linden when it is in bloom. Here, amidst all of the other odors of the city, a youngster can have the chance to appreciate still another aspect of the outdoor environment.

There is no necessity to go to a meadow to find honey bees at work. When these trees are in bloom, bees are always present. They may also be found around the play yard, attracted, along with yellow jackets, to some spilled juice or other sweet. Just as much discussion on colonial insects can be initiated here as could be introduced on a scheduled field trip. A small apiary actually exists within a mile of this school, and a field trip to that location could be a culminating activity.

Let's go on an ant hunt! It may not seem as exciting as a bear hunt, but most youngsters are fascinated by watching ants follow one another, carry food, touch antennae, etc.

Where and how do the ants live?
Why are they here?

The basic interrelations of living things and environment are present here in the city just as they are outside. There are several excellent sites at this school where ants can be found. There are numerous colonies in the old cemetery, and others can be found in the infiltration areas for the trees.

Would you prefer to study larger animals? If you have taken a field trip to a truly natural area (not a zoo or park) you know that larger mammals and birds are usually seen only in brief glimpses. Why not study pigeons? Every inner-city school has its share of pigeons, and they are constantly available for observation. Many of the pupils can watch the nesting process from their apartment windows. With careful observation they may learn to identify particular birds in the flock that frequent the school yard. Soon, one or more of the birds will receive names based on some peculiarity of appearance or behavior. How and why the pigeon fits into the city environment will become a natural topic, and another bit of ecological understanding will have developed.

The wild mammal most often available for class observation in the city is the gray squirrel. In the nearby cemetery one or two squirrels can be seen almost every day.

Why do the squirrels live here?
Why don't they come to the school yard (as the pigeons do) for food?
Why don't we have more and more squirrels each year?
Why are there so many rats around some buildings but so few squirrels?

WITH a little effort, any urban teacher who wishes to can introduce students to the out-of-doors without restrictions of budget or weather. While the major thrust of this article is directed toward the elementary school program, many similar but more sophisticated activities might be done in secondary school to accomplish a similar increased awareness of the environment. Simple analysis of rainwater in the chemistry laboratory may reveal a number of impurities that can be traced to atmospheric pollution. Run-off volumes can be computed and ideas developed for salvage of this water. Developing a check list of plants and animals found in the school area could be a year-long project in a biology class.

Just outside the building, there is an outdoor environment waiting to be used. Of course, it has been modified by man—today, most of our environments show man's modification to a greater or lesser extent. This is really the crux of the whole problem. Man has, up to now, used and abused the environment with little thought for the consequences. Now these abuses are beginning to catch up to us. In 10 or 15 years the young people who today are in our public schools will be voters, business men, legislators, and educators. If the development of ecological consciousness is desirable (and many people think it is essential), then the beginnings must be made at an early age and with everyone, not just with those who live on the urban fringe or in more rural areas. □

GENERAL

Particulates Provide Proof of the Pollution Problem

BARRY WARNER, Science Teacher, Seth Low Intermediate School, 99 Avenue P, Brooklyn, New York

There is a great deal of evidence around us today suggesting that residents who live in areas that have an air pollution problem don't give much thought to it.

We inhale about 30 pounds of air each day and, with the air, varying amount of pollutants. The particulates, finely divided solids such as smoke and dust, enter the atmosphere from the combustion of coal and fuel oil as well as incineration. The largest of these particles have a tendency to settle out of the air. When inhaled, they can hamper the performance of lung function.

Particles, both liquid and solid, are enormously complex and can be considered the most widespread of the pollutants. Processes of erosion, grinding, and spraying produce particles as small as 10 microns, such as industrial dusts and ash.

Gravitational settling is the main mechanism by which particles are removed from the air. Particles generated in the urban atmosphere normally remain airborne for only a few days. If very small, they may remain airborne for several weeks.

As the smoke and dust pollute the air, there is a rising incidence of respiratory disease. Emphysema and chronic bronchitis constitute a health menace of major magnitude. The air we breathe has not only life-supporting properties, but potential life-damaging properties. The well-being of man depends on inhaling air that has a qualitative and quantitative balance. Normally, body contact with particulates in the ambient air occurs at the exposed membranes where they are particularly sensitive to injury.

Air is not an unlimited and inexhaustible resource, and young people must be made aware of that fact. A simple technique can be used by any student in order to point up the problem of particulate pollution.

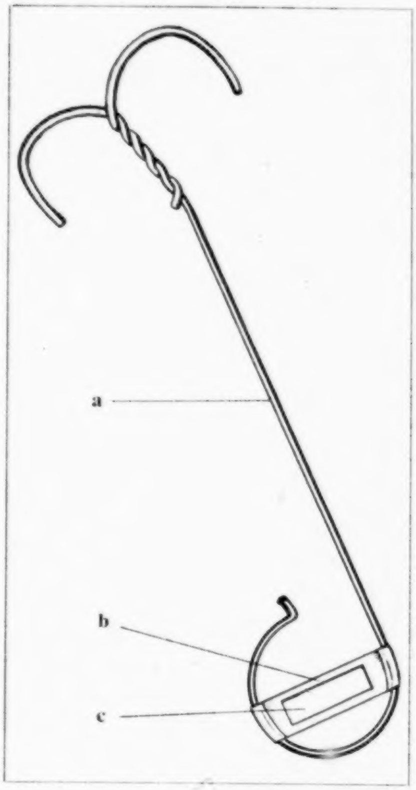


Figure 1. A device for collecting particulates in the air. A hanger (a) was cut, elongated, and bent in a circular manner around a can (b). A piece of tape was placed around the can sticky side up. The tape was used to hold a glass slide (c) coated with Vaseline. The hanger was then positioned outside the window sill.

The technique we employed was to collect particulates on a sampling slide and then determine the amount of particulate matter collected, by simple weighing. (See Figure 1.) The placement of the collector is important because the particles constantly settle out, and a maximum number of particles should be collected for significant results.

After a period of two weeks, the slide was taken in, carefully placed in a shoebox, and brought to school where it was weighed. The calculations involved are shown in Figure 2. The utilization of this scheme can show that the dustfall in large cities, such as New York, Chicago, and Detroit, can be as much as 50 tons per square mile per month.

It is unreasonable to expect that we can put a stop to all combustion, a chief source of particulates. It is logical, however, to expect that the clearing of the air is desirable in the interest of safeguarding human health. Student awareness can influence community and local action for environmental quality. ☐

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Period of Time	*Net Gain in Grams*	*Size of Slide (sq. in.)*
2 weeks	.021	3

Mathematical conversion factors:

$$1 \text{ gram} = 1.102 \times 10^{-6} \text{ tons}$$
$$1 \text{ sq. in.} = 2.490 \times 10^{-10} \text{ sq. miles}$$
$$\frac{.021 \text{ gm.}}{3 \text{ sq. in.}} = \frac{.0220 \times 10^{-6} \text{ tons}}{7.47 \times 10^{-10} \text{ sq. miles}} = \frac{22 \times 10^{-9} \text{ tons}}{7.5 \times 10^{-10} \text{ sq. miles}}$$

Total equals 29 tons/sq. mile in two-week period.

Figure 2. Method for calculating the amount of dustfall.

SOLID-WASTE RECYCLING— EARTH SCIENCE IN A REAL SITUATION

When a teacher seeks out a real situation for a multidisciplinary course, when students explore a current problem in relation to their own town, the whole community benefits. Here, a teacher describes his objective in shifting the focus of an earth science course, and the students describe their venture into community research.

TO PRACTICE THE DISCIPLINE . . .

MICHAEL C. FRANZBLAU, Earth Science Teacher, Mamaroneck High School, Mamaroneck, Westchester, New York

VARIATIONS in course structure may accomplish little unless the course can be related to a real situation of some concern to students. Such a situation for our earth science class was suggested by a glass-recycling activity initiated by Herbert Golden, an environmentalist living in Larchmont. He shared my view of the potential value of participation of high school students in a multidisciplinary project within their community which would encourage the joint action of community adults, students, and local officials. Therefore, we decided to approach the problem of solid-waste recycling as a professional scientist would, gathering data, formulating and testing hypotheses, drawing conclusions.

Recycling is an arena embodying many disciplines; it is directly concerned with psychological and philosophical attitudes, economics, technology, and politics. Thus, the study of earth systems could well focus on solid-waste recycling and give each participant a sense of the complexity of a contemporary social phenomenon and the power of an analytical approach to its solution. The earth science class formed a Recycling Study Group to work on this problem.

The following report by the students in the Recycling Study Group describes their activity over a period of several weeks. The report was later presented to the Westchester Recycling Conference, arranged, with the help of volunteers, by the staff of the Pinebrook Center for Environmental Studies, a not-for-profit corporation created to permit us to engage in activities in the area of the relationship of man to his environment. The report met with widespread interest and became a focal point for discussion throughout the workshop sessions.

The report was also presented to the Conservation Advisory Committee of the Town of Mamaroneck, which in turn recommended it to the Town Board. The Town Supervisor agreed on the basis of the findings to consider the establishment of a municipally managed newspaper recycling effort and invited our group to aid in the planning of this activity.

The 25 students who participated in this project have become aware of their potential for effecting change in long-established institutions. The scientific methodology they employed provided their conclusions with a credibility not readily attained in the conventional high school project. They are eager to continue their efforts in this area and regard themselves as budding social scientists.

The following article is a summary of the report of the community study conducted by the student group.

TO LEARN ABOUT OUR TOWN . . .

RECYCLING STUDY GROUP, Mamaroneck High School, Mamaroneck, New York

THE Recycling Study Group is an organization of earth science students at Mamaroneck High School, their teachers, and various community adults. Its purpose is to investigate the mechanics and economics of solid-waste recycling as a possible solution to the waste-disposal problem, taking into account the interdependence of political, sociological, psychological, and philosophical aspects of recycling and the importance of community education.

Recycling presents an alternative to the disposal of solid wastes by incineration or burial in sanitary landfills, which not only destroy and despoil the landscape, but permanently remove much-needed materials.

The students began by looking into some of the background of the solid-waste problem, both as regards the initial cost in resources used and the problem of disposal mechanisms and costs. They discovered, for example, that: The production of aluminum from bauxite consumes nearly eighty times the electric power that is required to reuse or recycle aluminum products. The iron and copper content of scrap heaps is immensely greater than that found in the ores of these materials; but the reuse of scrap metal by the secondary materials industry is hampered by the freight rates for rail transport of metal scrap. Solid wastes from paper production and consumption in the New York region amounted to 17 million tons in 1965, or half of the total amount of solid waste collected. Recycling of newspapers in New York City alone would remove more than 1,000 tons per day from the total amount of collected wastes. The recycling of paper, besides freeing forest land for esthetic and recreational uses, would have major impact on solid-waste management.

Present technology affords the possibility of reclaiming usable materials amounting to nearly 100 percent of all solid wastes. In practical terms, it is possible to reuse between one-third and one-half of all solid wastes from the home. Required, however, is a genuine desire by the public to participate in the conversion of present sanitation systems which are based on a philosophy of use/disposal.

Because of the high cost of extra hand labor that would be required to separate solid wastes after collection, the adoption of a solid-waste recycling program at present must involve voluntary home separation of wastes into various categories. Therefore, in its study to determine the feasibility of replacing the present waste-management system in the community with a municipally managed solid-waste recycling system, the group focused on three aspects of the waste-management problem:

1. The mechanics of voluntary separation of solid wastes in the home. Eleven families in the community participated in a four-week experimental separation process, which led to an analysis of the total annual production of recyclable materials in the Larchmont - Mamaroneck area.
2. An analysis of the potential economic impact of total voluntary solid-waste recycling on the sanitation budget of the Village of Mamaroneck.
3. Surveys of the attitudes of residents in this community toward recycling.

With the participation of 11 families in the community, the group investigated two questions: What fraction of the materials brought into the home became solid waste? Of all wastes produced, what fractions fell into the categories of paper, glass, metal, and wet wastes? The first three are immediately salable; the last can be removed from the disposal process by composting.

THE participating families, for four weeks, weighed all incoming goods including groceries, newspapers, and mail. They also separated and weighed in each category all solid wastes produced during this period. Table 1 presents the results of the 11-family, 48-person sample group. In general, the income level of participating families was above the average income level in the town, and far above the national average.

As the table shows, the average weight of goods brought into the home each month was nearly 440 pounds or 100 pounds per person per month. Approximately 45 percent of the incoming material became solid waste, with paper constituting 34 percent of this total in contrast to the widely quoted 50 percent level nationally. A possible source of this discrepancy was the disposal of some paper products as "wet garbage."

Using the information collected, the students computed, on a townwide basis, the potential savings in the sanitation budget if (a) 100 percent of the recyclable solid wastes produced were voluntarily separated in the home and collected by the municipal sanitation system without additional collection expenses, and (b) the materials were transported to the purchasers of recyclable wastes and sold. Mamaroneck now pays 6.3 cents per ton per mile for hauling waste to Croton Point for dumping.

A summary of the calculations is presented in Table 2. The total expense for removal of the 60 percent of solid wastes that could be recycled was found to be $9,000, or $1.90 per ton. This may be compared with the present cost of $19.65 per ton. As a consequence of the recycling of the portion of solid waste collected annually in the Village, the sanitation budget could theoretically be reduced more than $80,000 or half the cost.

This startling result must be immediately qualified by the presence of several factors which have necessarily been ignored. Among these are the difficulty in achieving 100 percent participation and cooperation in voluntary home sep-

Table 1. Results of consumption/waste production for sample group.[a]

WASTE CATEGORY	WEIGHT	PERCENT OF TOTAL WASTE
	pounds	
Wet garbage	871	39.8
Paper	741	33.9
Metal	173	7.9
Glass	402	18.4

[a] Based on a four-week program, with 11 participating families (a total of 48 people). Total incoming goods = 4,822 pounds; total waste produced = 2,187 pounds.

Table 2. Recycling-based sanitation expense for Village of Mamaroneck[a]

Material	Percent Weight	Total Tons	Transportation Cost per Ton[b]	Collection Cost per Ton	Transportation and Collection	Sale Price per Ton	Net Collection-Disposal Cost per Ton	Total Net Expense/Profit
Paper	34	2640	$3.50	$13.44	$16.94	$ 8.00	$ (8.94)[c]	$(23,600)
Glass	18	1440	3.28	13.44	16.72	20.00	3.28	4,700
Ferrous	7	545	4.84	13.44	18.28	10.00	(8.28)	(4,500)
Aluminum	1	78	2.08	—13.44	—15.48	200.00	184.52	14,400
Total	60	4703						$ (9,000)

[a] Based on annual tonnage of 7,800 tons collected by Village of Mamaroneck.
[b] Computed on basis of closest operating markets: North Bergen (glass), Garfield (paper), Bronx (aluminum), Elizabeth (ferrous cans).
[c] Parentheses indicate net cost, lack of parentheses indicate net profit.

aration of wastes, the problems inherent in coordinating and integrating two simultaneous types of collection (unseparated and separated wastes), the fluctuation in markets for recycled products (particularly paper), and the overestimation of the fraction of paper which is recyclable. Nevertheless, the potential of solid-waste recycling for reducing the sanitation expenditures of a municipality is of real significance. Its success depends, however, on the attitudes of the citizenry toward voluntary separation and its concern for environmental values.

THE NEXT part of the study investigated community attitudes toward solid-waste recycling, taking into account the interrelationships among economic, social, moral, and political aspects of the solid-waste problem. A questionnaire was sent to 1,000 randomly selected residents of Mamaroneck and Larchmont (total population 40,000). Returns were received from 360 people, an unusually large response to a survey of this size. Nevertheless, when only a portion of a sample is returned, there can be no certainty that bias has been avoided. It can be assumed that the cross section of respondents is more politically active, more affluent, and better educated than a truly representative cross section would be. This seems to be true of the respondents, for 80 percent voted in the last election, and the average respondent is a college graduate in his forties, earning from $15,000 to $30,000 per year.

Following are some of the questions and the percent of various responses:

1. Some people believe that waste disposal is one of the most serious problems in the country, in that our air, water, and land are becoming increasingly polluted. They believe that we are approaching a time when there will be no more space to dump garbage and that the solution to this is the re-use of these materials. This is known as *recycling*. The idea is that each family would put all its wet garbage into one container, glass and metal into another, and paper into a third. The town would then be able to sell the trash to industry. Do you believe that pollution of this type is

	percent
One of the most serious problems	39
A major problem	54
A minor problem	6
No problem	1

2. Would you be willing to put your garbage into three separate cans every day: one for wet garbage, one for cans and bottles, and one for paper?

	percent
Willing	92
Not willing	4
Not sure	4

3. Would you be in favor of your town starting a recycling program if it meant that your taxes would go up a few dollars a year?

	percent
In favor	68
Not in favor	18
Not sure	14

4. What if the town could make money from the operation so your taxes would only go up for the first year and then down again below their original level for waste disposal?

	percent
In favor	88
Not in favor	5
Not sure	7

5. Would you be more or less likely to vote for a local political candidate *if* he were for a comprehensive waste-recycling program?

	percent
More likely to vote for	75
Less likely to vote for	4
Not sure	21

The major conclusion that can be drawn from this study is the feasibility of solid-waste recycling in the community under these conditions:

1. The desire of the citizenry to cooperate by voluntarily separating solid waste in the home.
2. The stability of the demand for recycled materials.
3. The willingness of municipal government to make the necessary alterations in the present sanitation system (mostly schedule changes).

THE RESULTS of this study strongly suggest the appropriateness of a pilot-test recycling project in a selected section of this community. Such an experiment in municipally managed recycling would be of immense value to the community as a whole, both from an economic and environmental standpoint. The design of this pilot program would be a joint student-community-government effort which could be incorporated into the curriculum of Mamaroneck High School. Participation of the students in the process of educating the citizenry in the mechanics of recycling is, in our opinion, of paramount importance.

In the course of the present study, group members report that "our attitudes toward our environment have matured. We have come to regard man as a participant in, rather than master of, his natural surroundings. We have learned much about our community; the dynamics of its operation, the attitudes of its citizens, and its potential for creating and maintaining an environment which can serve the needs of its inhabitants." □

ENVIRONMENT

Air Pollution—Detection and Abatement

RICHARD KRAFCHIK, Helping Teacher, Prince George's County Public Schools, Upper Marlboro, Maryland, and Participant, Academic Year Institute for Science Supervisors, University of Maryland, College Park

Prince George's County is a suburb of Washington, D.C., and has its share of air pollution as a result of heavy commuter traffic and industry. There is great interest in air pollution, even at the junior high school level, but there are few materials on the subject which are appropriate for this age group. Upon contacting the Division of Air Pollution Control of the county health department, it became apparent that Division staff had been approached by many other teachers looking for materials in this field. The Division readily agreed to serve as a resource for materials, and set about developing demonstrations and experiments that could be used in the junior high school classroom and adapted to other levels as well.[1] My role was to be that of "helping teacher," a liaison between the Division and the schools.

Seven exercises were developed from sampling techniques used by the Department of Health, Education, and Welfare and by the Prince George's County Department of Health. In addition, the Division drew freely from available sources; two of the most useful of these are listed in the references at the end of this article. The end-product was a 16-page teachers manual titled "Air Pollution Experiments."[2]

Some of the experiments, such as that illustrating the deterioration of nylon, are undoubtedly familiar to teachers. I would, therefore, like to describe three exercises that may be less familiar. The first, Detection of Carbon Monoxide and Carbon Dioxide, illustrates the use of detector tubes in identifying pollutants. The following two exercises, Afterburner and Wet-Scrubber, illustrate current technological devices to curtail air pollution.

Detection of Carbon Monoxide and Carbon Dioxide

Glass detector tubes provide a method for determining the presence of various gases in the atmosphere. The detector tube is a cylindrical glass tube with closed ends, approximately 6 mm in diameter and 10 cm in length. Inside the tube is a chemical reagent sensitive to the gas you wish to detect. To use the tube, the closed ends are snapped off, and a given volume of the air to be tested is pumped through the tube. A color change occurs that is related to the quantity of the gas present in the sample.

The most difficult problem with using these tubes is knowing the quantity of air that passes through them. A rubber aspirator bulb with a 100 cm^3 capacity is available from Mine Safety Appliances (MSA) Company,[3] but it is also possible to buy an inexpensive rubber bulb pump in a drugstore and calibrate it yourself. To calibrate, the bulb is squeezed once, and the air passing through it is directed through a rubber tube to a bottle arranged to collect gas by the water-displacement method. The volume displaced is measured. Then the number of squeezes to achieve the required volume of air flow through the detector tube is computed.

Procedure: Obtain a detector tube, and carefully break open both ends. Squeeze the bulb. Place the end of the detector tube which is more tightly packed with crystals into the rubber tubing. Make an air-tight connection by wrapping a rubber band around the tubing that holds the detector tube.

Use the smoke emitted from the end of a cigarette as a source of carbon dioxide. Keep the open end of the detector tube directly in the stream of smoke. Release the bulb, thus sucking one bulb volume of gas through the detector tube. The blue reagent crystals in the tube will change to a light gray color in the presence of carbon dioxide.[4] Measure the length of the gray stain; then use the calibration scale supplied by MSA to calculate the percent by volume of carbon dioxide in cigarette smoke. The value you will obtain is only approximate, however, since one cannot control the amount of time the gas is in contact with the reactor chemical when using a squeeze bulb.

A similar procedure may be used to test for carbon monoxide. Automobile exhaust may be used as a source of the gas. (**Caution:** Carbon monoxide is a deadly gas; do not run an automobile motor in an enclosed place.) The yellow detector chemical will become brown in the presence of carbon monoxide.[5] Measure the length of the brown stain, and consult the calibration scale to find the carbon monoxide content. Test first directly at the carbon monoxide source; then vary the distance from the source. You may wish to test a heavily traveled area such as a superhighway at different times of the day.

The Department of Health, Education, and Welfare has established threshold limits for each of these gases. The threshold limit is the maximum safe allowable limit of a specific gas in the atmosphere. Anything over this limit is a hazard to health. The threshold limit for carbon dioxide is 5,000/1,000,000 (5,000 ppm) by volume of air. The threshold limit for carbon monoxide is 50/1,000,000 (50 ppm) by volume of air.

Wet-Scrubber

The wet-scrubber is one of the most common anti-pollution devices employed by industry. It depends on the fact that when a polluted gas stream is brought into contact with water, the pollutants are absorbed by the water.

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[1] The materials were actually written by Frederick V. Wootton, Sanitarian II, Division of Air Pollution Control, and Jo Ellen Baker of the Department of Health Education, Department of Health, Prince George's County, Maryland. They were field-tested by Michele Bellante at the Thomas Johnson Junior High School, Prince George's County.

[2] Single copies are available at no cost from the Prince George's County Department of Health, Division of Air Pollution Control, Cheverly, Maryland 20785. Send a self-addressed, 8½ x 11-inch envelope with 32 cents return postage.

[3] Mine Safety Appliances Company, Pittsburgh, Pennsylvania 15208. MSA has detector tubes for carbon monoxide, carbon dioxide, sulfur dioxide, and many other gases. A package of 12 tubes of any one type costs approximately $7. Write for a free catalog.

[4] Carbon dioxide detector-tube reaction: An organic amine and the indicator thymol blue are impregnated on activated alumina. These chemicals change from blue to nearly white when in contact with carbon dioxide.

[5] Carbon monoxide (length of stain) detector-tube reaction: Carbon monoxide reacts with potassium-pallado sulfite impregnated on silica gel to give a brown stain.

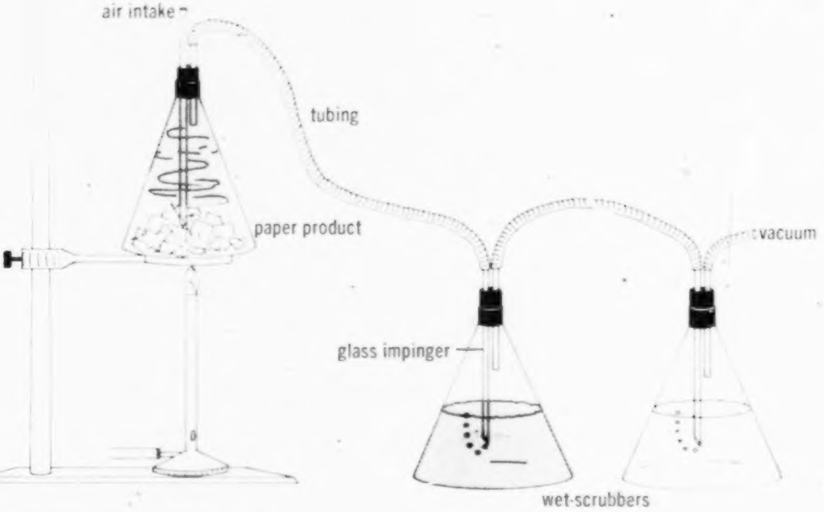

Figure 1. Apparatus for demonstrating the wet-scrubber, a device used by industry to remove pollutants from gases.

Procedure: Set up the apparatus as shown in Figure 1. Place a paper towel in a 500 ml flask, and place this above the Bunsen burner. Using a double-hole stopper that makes an airtight seal with the flask, insert a 5-inch section of glass tubing through one of the holes. The glass tubing should reach approximately one-half inch from the bottom of the flask.

Insert a 1-inch piece of glass tubing into the other hole of the stopper. Connect approximately 1 foot of rubber tubing to the 1-inch piece of glass tubing, making sure that an airtight seal exists.

Fill a second 500 ml flask approximately three-fourths full of water. Taking a second double-hole stopper, place two 1-inch pieces of glass tubing into the top holes. Connect the rubber tubing from the first flask (the combustion chamber) to one of the pieces of glass tubing in the second stopper. Insert the wide end of the glass impinger into the bottom of the same hole in this second stopper which is connected to the rubber tubing. The glass impinger is a straight piece of glass tubing drawn to a smaller diameter at one end, which causes the release of smaller bubbles. These smaller bubbles bring more gas in contact with the water. Taking a second piece of rubber tubing, connect it to the remaining unused glass tubing. Hook this rubber tubing to a vacuum source.

Heat the first flask (the combustion chamber) until smoke appears. Draw a vacuum on the system causing a stream of smoke to be drawn through the second flask (the wet-scrubber).[6] Observe the change in the color of the water. If smoke collects in the second flask above the water, a second wet-scrubber can be added.

Afterburner

The complete combustion of fuels containing carbon and hydrogen yields water vapor and carbon dioxide. Most air pollution results from material that is not completely burned. A fire that smokes is a familiar example of incomplete combustion. These smokey gases can be reignited by an afterburner to cause the further combustion of the particles that cause air pollution.

Procedure: Arrange a ring stand as shown in Figure 2. Clamp a rubber strip, and mount it under the inverted funnel as shown. (**Caution:** Use a small piece of rubber, but do not use rubber bands or other rubber products which will "pop" and cause burns.)

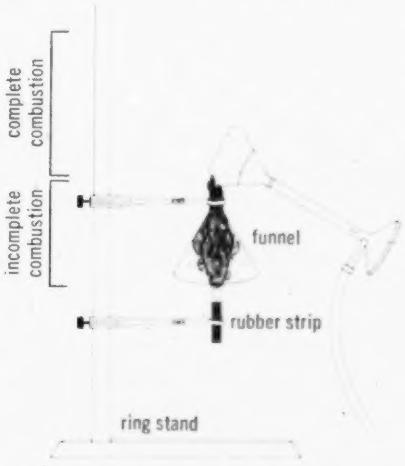

Figure 2. The function of an afterburner in reducing pollution can be shown.

Ignite the rubber strip, thus producing a black stream of smoke, the unburned portion of the rubber. Make sure that the stream of smoke is directed up through the funnel. The funnel is employed to simulate a chamber comparable to a boiler or incinerator. The neck of the funnel is analogous to a smokestack or chimney. Position a Bunsen burner by hand above the stream of smoke until the smoke is completely burned and can no longer be seen.

Explore with your classes the kinds of industries that use wet-scrubbers and afterburners and the advantages and disadvantages associated with each. ☐

References

1. *Air Pollution Primer.* National Tuberculosis and Respiratory Disease Association. New York. 1969.
2. Hunter, Donald C., and Henry C. Wohlers, Editors. *Air Pollution Experiments for Junior and Senior High School Science Classes.* Education Committee, Mid-Atlantic States Section, Air Pollution Control Association. 1968. (This publication is available for $1 per copy. In quantities of ten or more, price is 50 cents per copy, plus postage. Requests for copies should be addressed to: Student Manual, Air Pollution Control Association, 4400 Fifth Avenue, Pittsburgh, Pennsylvania 15213.)

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[6] Use a water-siphon type draft on a low-pressure mechanical pump. Too much pressure will pull water through.

GENERAL

Air Pollution Tests Using the "DEMA"

L. M. WILT, Science Teacher, Dover Intermediate School, Dover, Pennsylvania, and Graduate Student, Arizona State University, Tempe, and THEODORE W. MUNCH, Professor of Science Education, Arizona State University, Tempe

The nationwide "Earth Day" last spring was one good indicator of a rising national interest and concern with the environment. The dire need for action in the area of air pollution control is apparent when school children in Los Angeles are allowed to run only on alternate days during playground activities. Legislation for atmospheric control is being discussed on national and state levels, and a few laws have been passed. However, recent studies indicate that very few schools or textbooks include information or student activities on atmospheric pollution.

Student studies of the atmosphere are desirable, if not necessary, additions to all science programming. A necessary tool for making a study of air pollution is a high-volume air-moving device. Figures 1 and 2 show a simple, inexpensive, and effective tool for use in making atmospheric tests. Following is a description of selected items for making and calibrating the DEMA (DEvice for Measuring Air).[1]

The DEMA motor was obtained from a vacuum cleaner repairman who, on learning the purpose, contributed the motor and the aluminum housing. The housing was screwed onto the air intake side of the motor, and a handle was soldered onto the motor casing. A scrapped hose connector fitted into the air intake opening very snugly. A fiber flower pot was pressed on the outlet end of the motor to enable use for pressure or vacuum conditions. If not for the gift, total cost would have been $5.

The filter holder was made from a can which comes fitted with a plastic cover. The center of the plastic cover was cut out and used to seal a milk filter over the top of the can. A one-inch pipe was soldered into the metal end for attaching to the motor.

Computing the Volume of Air Flow

To obtain comparative test values, it is necessary to measure the volume of air flow. This can be done in a number of different ways, depending on the grade level involved. A few sample calculations follow.

- Using a 30-gallon (.114 m^3) trash can liner, the volume of air moved per minute is easily calculated by measuring the time it takes to fill a bag or to fill a bag in a known size container. Repeat four or five times to obtain average time to fill bag.

$$\frac{0.114\ m^3}{1} \times \frac{1}{\text{average no. of sec to fill bag}} \times \frac{60\ sec}{1\ min} = m^3/\text{min of air}$$

- Figure 3 shows an easily assembled arrangement for a more exact measurement of cubic meters per minute. By use of the manometer principle, the loss of pressure through the 0.0127 m orifice (0.5 inch) inside the union is measured by the difference in height of the mercury on each side of the union. The following formula can be used to determine the cubic meters per minute of air moved:

$$Q = KA\sqrt{2gh}$$

$$Q = (0.61)\cdot(1.27 \times 10^{-4}\ m^2)\cdot\left(\sqrt{2\cdot 9.8\frac{m}{sec^2}\cdot 3.54 \times 10^{-1}\ m\ of\ H_2O}\right)\cdot\left(\frac{60\ sec}{min}\right)$$

$$Q = .0121\frac{m^3}{min}, \text{ while}$$

Q = Quantity of air CMS

K = Constant 0.61

A = Orifice opening m^2

g = Gravity 9.8 m/sec^2

h = Pressure difference m of H_2O

$$A = \pi r^2\ (r = .0127\ m)$$
$$= 3.14 \times (.00635\ m)^2$$
$$= 1.27 \times 10^{-4}\ m^2$$

$$h = .026\ m\ Hg \times \frac{13.6\ H_2O}{1\ Hg}$$

$$h = 3.54 \times 10^{-1}\ m\ of\ H_2O$$

- Other methods, such as measuring the cubic meters per minute against an anemometer, could also be used. Direct the air against the cups of an anemometer and measure speed in meters per second. Measure diameter of the tube at the air outlet and compute as follows:

$$\text{meters per second} \times \frac{\pi r^2 m\ (\text{area})}{1} = \frac{m^3}{\text{sec of air}}$$

Tests Using the DEMA

Each area of the country will have certain atmospheric problems which are of most concern. Maricopa County in Arizona is particularly concerned with particulates, carbon monoxide, and sulfur dioxide.

Particulates can be measured by attaching the filter and running the motor under different atmospheric conditions, for different lengths of time, at different hours, etc. The filter papers can be used to set up a 0-100 standard based on reflected light as measured with a light meter. (Figure 4) If quantitative determinations are desired, use the manometer with the filter (minimum 3-hour running period), and weigh the filter paper before and after passing the air through it. The measurements obtained are weights of contaminants per volume of air sampled.

A relatively simple test for the stronger acids in the atmosphere (excluding CO_2) can be performed as follows. Put two pieces of filter paper (for strength) in the filter

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[1] The authors are indebted to Elbert C. Weaver for ideas published in *Scientific Experiments in Environmental Pollution*. Holt, Rinehart and Winston, Inc. New York. 1968.

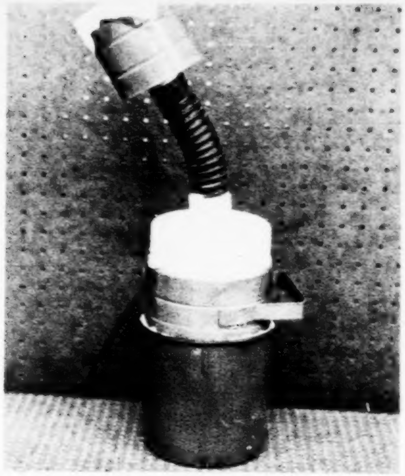


Figure 1. The completely assembled DEMA.

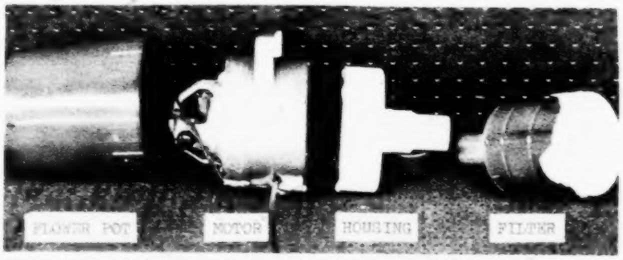


Figure 2. View of the disassembled DEMA showing component parts.

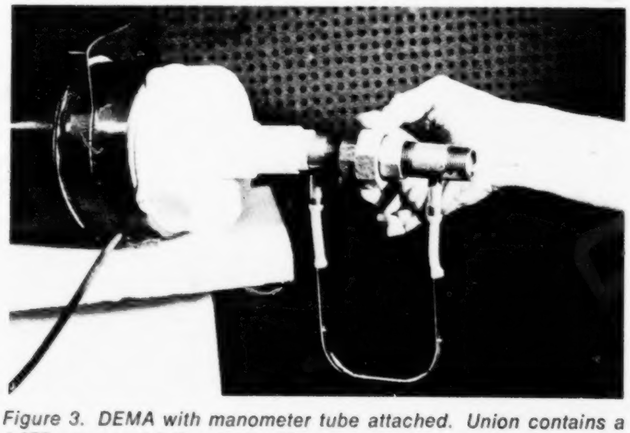


Figure 3. DEMA with manometer tube attached. Union contains a 1.270 cm constriction in it. Mercury can be seen in glass tube.

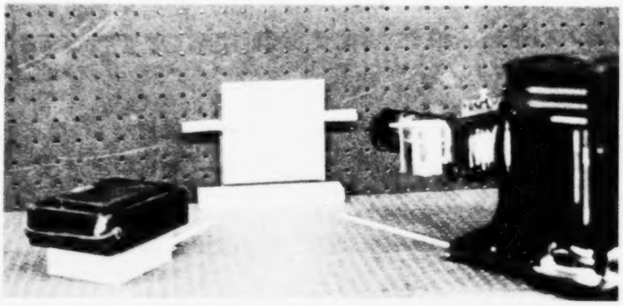


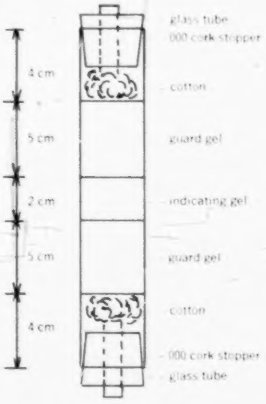
Figure 4. On right is projection lantern with narrowed aperture. Light meter is on left. Angle of incidence must equal angle of reflection. Clothespins allow easy change of filter paper.

holder. Place one drop of glycerine on the paper, add one drop of methyl orange indicator (.01M) solution and one drop of sodium bicarbonate ($NaHCO_3$) solution for a buffer. (This minimizes the effect of CO_2, while SO_2 and other stronger acids will show an effect.) The time required for an orange-to-red color change is a measure of atmospheric acidity. First, run a trial test using the fumes of a strong acid. Then any areas (kitchens, dressing rooms, laboratories, etc.) which contain a detectable amount of acid can be compared to the original test. More exacting quantitative methods of acid measurement by titration can be obtained by referral to Reference 2.

Testing the outside atmosphere for carbon monoxide is a very critical and difficult procedure. However, interesting comparative results can be obtained using enclosed areas. A special filter tube must be prepared as diagrammed below. Attach the DEMA, and measure the length of time necessary for the air passing through the tube to change the color of the silica gel. This is a measure of the CO content of the air. The color change is from yellow to green to blue. Lighted matches are good sources of carbon monoxide. (Warning: Carbon monoxide is a dangerous gas and should be used with care.)

Preparation of Filter:

1. Clean a 7mm-bore filter tube with sulfuric acid, rinse with distilled water, and allow to dry.
2. Carefully pack as diagrammed, tapping lightly before setting last stopper.
3. Indicating gel and guard gel can be obtained from Central Scientific Company.
   #38530 Silica gel, Indicating
   #38532 Silica gel, Refrigeration (guard gel)



The above are just a few of many possible ways the atmospheric test kit (DEMA) can be utilized. It is possible to measure practically any of the pollutants of the atmosphere: radioactivity, pollen, atmospheric aldehydes, etc. By referral to the listed references, specific experiments can be obtained. In many cases the level of difficulty can be adjusted for junior or senior high school. ☐

References

1. Lyon, Yolande. *Experiments for the Science Classroom.* State of California, Dept. of Public Health. 1968.
2. Weaver, Elbert C. *Scientific Experiments in Environmental Pollution.* Holt, Rinehart and Winston, Inc., New York. 1968.
3. *Air Pollution.* The University of the State of New York. The State Education Dept., Bureau of Elementary Curriculum Development. 1966.
4. *Air Pollution Experiments.* High School Edition. Cooperative Extension Service, Rutgers Univ., Rutgers, New Jersey. 1967.

GENERAL

Simplified Airborne Solid Sampling

G. WILLIAM REYNOLDS and ROGER W. WARD, Science Division, State University of New York, Albany

The sophistication required for obtaining a quantitative measure of air pollution is often discouraging for the beginning science student. The following article describes an easy visual evaluation and sizing of matter settled from the atmosphere. The criteria used in developing this exercise were published by the NSTA committee on conservation and environmental studies (*The Science Teacher,* May 1970). In addition, it seemed practical to use materials that were readily available, simple, and easy to fabricate with a minimum of special equipment.

The basic collecting device is a strip of manila folder or light cardboard twice the size of an ordinary microscope slide and folded in half. Five holes are punched through one side of the sampler with a standard hole punch (.6 cm diameter). The holes are then covered with a strip of clean transparent tape, with a small tab left to seal the cover half to the sample half. (Figure 1) Care should be taken to keep the sticky surface of the tape free from any foreign particles, such as fingerprints, paper fragments, or dust.

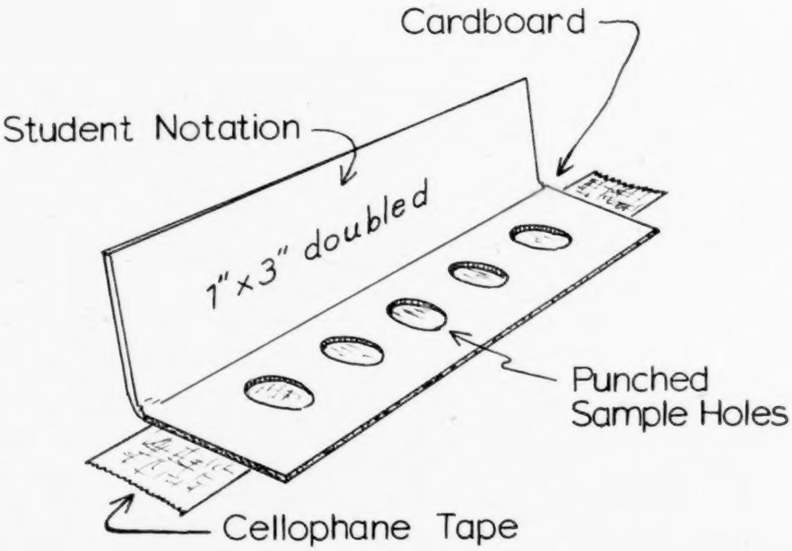


Figure 1. The basic device for collecting airborne particles is a strip of manila folder or cardboard with punched holes covered with transparent tape.

When preparing collectors for a class, cut, crease, and fold the strips before applying the tape. Then, place a long strip of the transparent tape on a table surface, gummed side up. Place the sample collectors on the tape so that a sticky surface shows in each punched hole. Separate the collectors with scissors, and seal the top closed to prevent inadvertent particle adhesion. Placing the sample collectors in small envelopes further insures that particles will be kept from the sticky surface until sampling is desired.

Students are given one or more samplers which they are to expose to the air at locations they select. When the student collects his sample, he should record the time and location of sampling on the foldover cover along with notation of any special conditions, i.e., relative wind velocity or number of days or hours since last area rain. Samples can be taken in a variety of places: indoors, on a window sill, a porch, etc. Telling the students that they will be observing and analyzing their own samples helps motivate them to make accurate observations and to take care in handling their collectors. (CAUTION: Do not place the collector where rain will fall on it. Excessive moisture deteriorates the collector and the gummed surface.)

When the samples are returned, each student should carefully examine his own collector with a microscope under low power. The collectors may be examined qualitatively. The student can develop a general relationship between the quantity and kind of particles on the gummed surface and the collecting time, wind conditions, and other noted parameters. A statistical approach to particle sampling can be added for those students wishing a more detailed and quantitative analysis. Using an

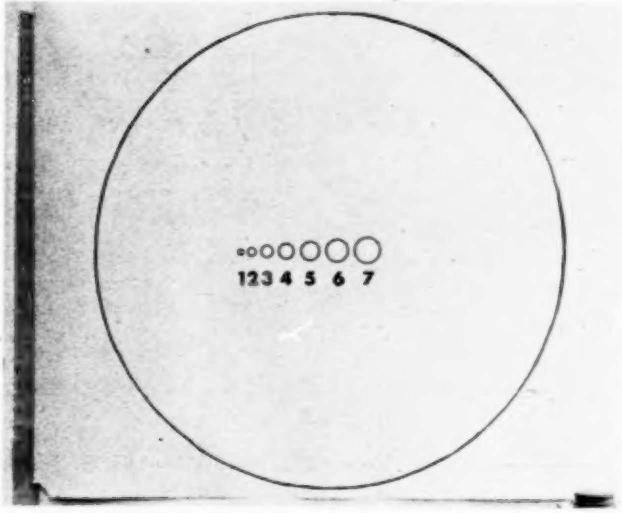


Figure 2. A simple reticle for sizing particles can be made by photographing a series of circles and then contact printing the negative on transparent base film. The circular positive can be easily slipped into the eyepiece of a microscope.

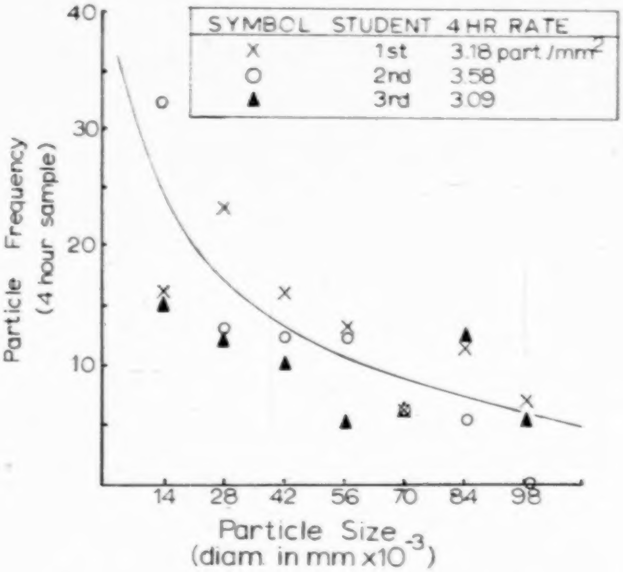


Figure 3. Student data indicating particle distribution by size.

ordinary student microscope, four separate fields of view, under low power, can easily be made in each of the five sample holes. Danger of overlap is reduced by orienting the field of view at the 12, 3, 6, and 9 o'clock positions near the edge of each sample hole. Repeating this procedure for different sampling times in a particular location can produce data on sampling time versus the average number of particles per field.

When viewing the collector qualitatively, the student will observe that the particles vary in size. To size the particles and to determine the relative number of particles in various size ranges, a measuring device must be added to the typical student microscope. Glass reticles for the eyepiece of the microscope may be obtained from a supply house, but these tend to be expensive in class quantities. A simple reticle can be produced photographically. A negative is made of a series of circles whose diameters progressively increase by integral multiples of the smallest circle in the series. Circle 2 should be twice the diameter of circle 1, circle 4 twice the diameter of circle 2, etc. (Figure 2)

The negative is then contact printed on transparent base film (lithographic film or similar high contrast film). The resulting positive set of circles may then be removed from the film with a number 14 cork borer. The circular positive can easily be slipped into the eyepiece of a microscope. Should the film have a slight curl, it may be held in place by using a retaining ring cut from a link of a spring, 2 cm in diameter. These circle sizes now provide a means of determining the relative size distribution of the particles observed with any particular eyepiece-objective combination. Sizing particles by comparison to the circles as they are counted will provide data for a histogram or graph relating size and frequency for a particular sample time and location. (Figure 3)

Calibration, either for or by the student, can add yet another dimension to the study. Stage micrometers are available from supply houses for this specific purpose. However, a simple stage micrometer can easily be produced as follows.

A standard meter stick was photographed at a 10 to 1 reduction in size (ground glass focusing was used to determine this) to produce a negative which was printed in quantity for the class on ordinary single-weight contact paper. The reduced photograph was placed on the microscope stage as a micrometer scale to determine the diameter of the field of view and the diameter of one of the circles in the film reticle.

If circle 7, for example, is found to be one division of the reduced meter stick, then it has a diameter of 0.1 mm or 100 microns. A simple ratio can determine the sizes of the remaining circles in the reticle; No. $1 = 14.3\mu$, $2 = 28.6\mu$, $3 = 42.9\mu$, $4 = 57.2\mu$, $5 = 71.4\mu$, $6 = 85.7\mu$, and $7 = 100\mu$. Similarly, the area of the field of view can be estimated. In a student microscope under low power (100X), the diameter was 14½ units or 1.45mm. This represents an area of 1.58mm^2.

Once data are obtained concerning the size and number of particles collected, it is possible to make some interesting extrapolations: the average rate of particle settling, the surface area of the particles (assuming a nearly spherical shape), and the size and number of particles smaller than those collected.

Such an open-ended investigation can easily be modified by the instructor to emphasize (1) the statistical approach in data collection and analysis, (2) the role of instrument calibration and possible error analysis, (3) the nature of one form of normally overlooked pollution, or (4) some workable combination of these three. ☐

ECOLOGY

The Effect of Smoke and Exhaust on Plant Growth

ANN L. ABELES, Assistant Professor, Science Department, Frederick Community College, Frederick, Maryland

Air pollution costs Americans at least $500 million a year in damaged plants. Some of the important air pollutants are sulfur dioxide, nitrogen oxides, carbon monoxide, ozone, peroxyacetyl nitrates (PAN), hydrogen fluoride, chlorine, pesticides, and hydrocarbons such as ethylene.

The effects of air pollution on plants were first studied during the mid-nineteenth century. The first pollutants to be investigated were sulfur dioxide, fluorine, and ethylene. At that time plant injury from ethylene was caused by leaking of illuminating gas.

Since then the development of automobiles and the tremendous increase in their number have resulted in automobile exhaust becoming an important source of air pollution. In addition to carbon monoxide, nitrogen oxides, lead oxides, and ozone, automobile exhaust puts large quantities of ethylene into the air. Automobile exhaust contains 500 parts per million (500 ppm) of ethylene. In fact, an idling car produces enough ethylene in one minute to defoliate a full-grown tree if the exhaust could be contained. The concentration of ethylene in exhaust is far greater than is that of the other plant-damaging constituents of exhaust. Carbon monoxide concentration in exhaust is 100 ppm; and nitrogen dioxide, 0.1 ppm. Comparison of the air in rural areas (0.005 to 0.001 ppm ethylene) with air around highways (0.01 to 0.10 ppm ethylene) and in shopping centers (0.05 ppm ethylene) shows that ethylene air pollution in cities is important. Burning plant material also produces ethylene. For example, cigarette smoke contains 500 to 1,000 ppm ethylene.

Ethylene is a gas with the chemical formula $CH_2=CH_2$. It is a plant hormone, and, therefore, ethylene air pollution has many effects on plant growth and development. Concentrations as low as 0.07 to 0.20 ppm can affect plant growth.

Ethylene causes such effects as inhibition of growth, formation of roots along stems and leaves (adventitious roots), formation of moisture droplets on the leaves and stems (guttation), drooping or curling down of leaves (epinasty), wilting and early death of flowers, and leaf fall (abscission). The major economic loss caused by high ethylene levels in our cities is damage to flowers.

The purpose of the following activities, developed with the cooperation of the U.S. Department of Agriculture, is to compare the effects of ethylene from an apple, from auto exhaust, and from cigarette smoke on bean plants.

These activities are intended for secondary school students; however, they can be used for primary students if more time is spent introducing the material. Since the use of a solution of potassium permanganate makes the experiment more complicated, you may wish to eliminate this part with younger students.

Some words of caution must be added. The collection of the automobile exhaust and cigarette smoke **must** be done under a teacher's supervision. Also, at least two adults should be present with young students during the collection of exhaust, because of the danger near running automobiles.

Materials

36 to 40 bean seeds of any garden variety, such as string beans, lima, pinto
8 to 10 pots, about 4-inch diameter
Enough sterile soil to fill the pots, or use vermiculite or perlite and fertilizer
8 large clear plastic bags, 25 to 26 inches tall by 16 to 18 inches wide
24 sticks, 12 to 15 inches tall
8 wire ties
2 ripe eating apples
2 cigarettes
200 ml of a 5 percent solution of potassium permanganate (10 g potassium permanganate dissolved in 200 ml water)
1 glass container which will hold at least 300 ml and has a cover
1 graduated cylinder, 100 ml
4 plastic dishes (empty cottage cheese or butter tubs) 12 oz size
4 circles of filter paper or very heavy paper towel, at least 15 cm in diameter
1 balance, suitable for measuring to the nearest gram
1 rubber aspirator bulb
1 or 2 short pieces of tubing which will fit the bulb and cigarettes

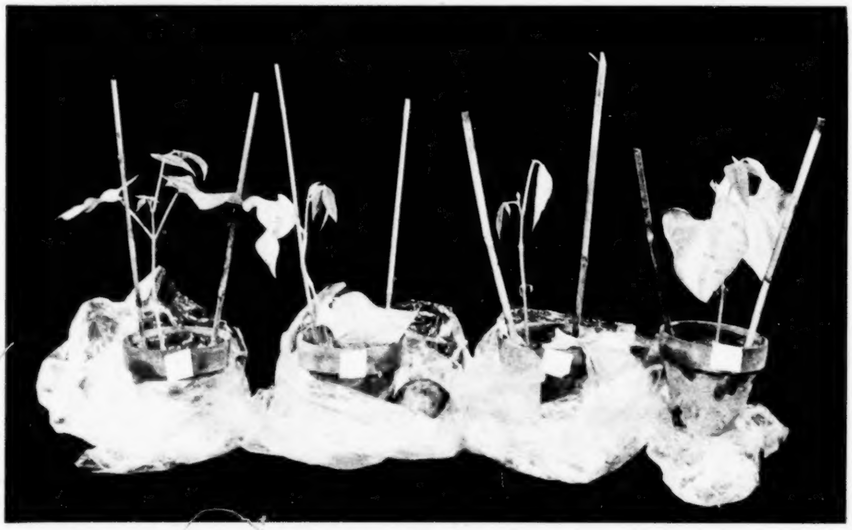
Method

1. About two weeks before you plan to do the experiment, plant the beans as follows:
   a. Fill the pots about three-fourths full of soil or vermiculite. Water thoroughly with room temperature water. Evenly space four beans on top of the soil and cover lightly with about ½ inch of dry soil. Pat down the soil lightly.
   b. Place the pots in good light and keep moist with room temperature water but do not overwater.
   c. Keep the plants above 65 F.
2. When the plants are about two weeks old, water thoroughly. Thin the plants so that there is one plant to a pot. Thin by cutting off the extra plants near the soil.
3. Weigh 10 g of the potassium permanganate and dissolve it in 200 ml distilled water in the covered glass container. Do not spill the permanganate solution as it will stain anything it contacts. **Do not drink it.**
4. Make a smoking machine by hooking the cigarette to the tubing and to the aspirator bulb.
5. Number the pots 1 through 8. Try to pair the plants so that 1 and 2 are similar to each other in height and leaf size, plants 3 and 4 are similar, etc.
6. Put each plant into one of the plastic bags, and arrange three sticks in the pots to support the bags so they do not crush the plants. All the bags should close at the top except those around plants 7 and 8, which should close at the bottom.
7. Fold the circles of paper in half and pleat them like fans. Open each into a loose cone and place tip down in the plastic dishes.
8. Put the following items in the bags with the plants:

Plant 1	nothing
Plant 2	plastic dish with paper cone
Plant 3	1 apple
Plant 4	1 apple and a plastic dish with the paper cone
Plant 5	nothing
Plant 6	plastic dish with paper cone
Plant 7	nothing
Plant 8	plastic dish with paper cone

9. Pour about 50 ml (about ¼ cup) of the potassium permanganate solution into each of the cones in the plastic dishes. The solution should creep up the sides of the paper to give a large surface area to absorb and oxidize the ethylene.

Figure 1. Typical plants after treatment. Plant 1 was the control; Plant 3 was exposed to the apple: Plant 5 was exposed to trapped exhaust; Plant 7 was exposed to cigarette smoke. All plants were kept in the plastic bags for two days.



10. Close the bags with plants 1 through 4 and tie tightly with the wire ties.

    NOTE: The next two steps involve the collection of the smoke and exhaust and **must** be done under the teacher's supervision.
11. In order to collect automobile exhaust you will need at least two people. **Use caution around the car and do not work in an enclosed area.** One person should support the plant and the dish of permanganate solution in the bag. These should be held about two feet away from the end of the tail pipe. While the car is idling, he should hold open the bag so that the exhaust blows into it for about *five seconds*. The opening of the bag should be at least a foot away from the end of the tail pipe so as to avoid burning the student or the plant.

    NOTE: You will have less trouble with heat if the car is started while its motor is cold. You may need to tip the plant and bag in order to aim the opening at the pipe. Be careful not to spill the permanganate solution.
12. After collecting the exhaust in bags 5 and 6, close the bags and tie with the wires.
13. Mark off 3 cm on each cigarette. Attach the tubing and rubber bulb to the end of the cigarette, 5 or 6 cm away from your mark.
14. Hold the cigarette below the opening of bag 7 so that the smoke will rise into the bag. Light the cigarette and slowly squeeze and release the bulb in order to "smoke" the cigarette. Allow only 3 cm of the cigarette to burn, then close and tie the bag. Be careful not to burn your fingers or the bag.
15. Repeat step 14 with plant 8, being careful not to spill the potassium permanganate.
16. Place all the plants in indirect light, at room temperature, for two to three days.
17. Each day examine the plants and record any changes in a notebook.

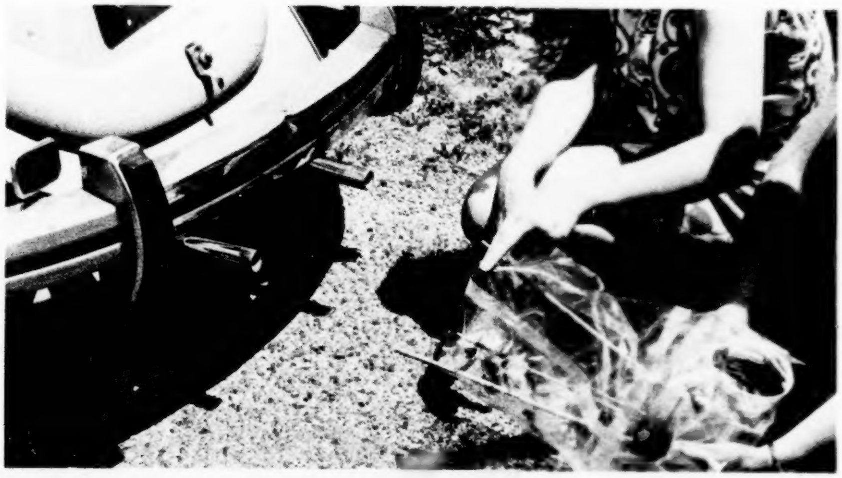


Figure 2. Caution must be exercised in the collection of automobile exhaust.

Look for such things as drooping leaves, and yellow or lost leaves.

18. After three days remove the plants from the bags and carefully describe the condition of each plant. (Figure 1)

Questions

1. What effects did the apple, exhaust, and smoke have on the plants?
2. Did the presence of the potassium permanganate solution affect the plants?
3. Does it appear that ethylene is an important component of exhaust or smoke? You should compare the appearance of the plants treated with ethylene from the apples with those treated with smoke and exhaust. You should also note whether some of these same effects are lessened or missing in the plants exposed to the potassium permanganate solution.

Additional Activities

1. Try other kinds of smoke, or vary the lengths of time for collecting the smoke.
2. Try other kinds of plants, especially flowers such as carnations or snapdragons if you can obtain them. □

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ACKNOWLEDGMENTS:

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DURING the last two years, I have developed with my high school science classes a series of discussions which relate science to other disciplines. The series was initiated and developed in response to a call by prominent scientists and humanists who pointed to a need to define more clearly for the layman the scientist's role in a democratic society.[1] If the educational process is to be effective in a technological culture, the layman must understand in some depth the relationships existing among the social sciences, the humanities, and the natural sciences.[2] Surely the secondary schools must shoulder substantial responsibility in assuring that the majority of citizens will be so enlightened. Yet, how are secondary school science teachers to facilitate this kind of perspective and understanding when faced with the many subject-oriented demands placed upon them, as well as the need to lay the foundations for further specialization? [3]

Our modern high school science curricula are moderately successful in achieving the last objective but are relatively unsuccessful in showing the important interrelationships between the sciences and other disciplines, and

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[1] Pauling, Linus. "The Social Responsibilities of Scientists and Science." *The Science Teacher* 33:14-18; May 1966.

[2] See, for example, Snow, Charles Percy, *Two Cultures and the Scientific Revolution.* Cambridge University Press, Cambridge, England. 1961.

[3] Conant, James B. *The American High School Today.* McGraw-Hill Book Co., Inc., New York. 1959. p. 15.

Science and Man

A Discussion Series for Secondary Schools

VINCENT N. LUNETTA

Science Department Head
Enfield High School
Thompsonville, Connecticut

they lack relevance to the lives of the majority of our students. Teachers generally do attempt to relate their science courses to the world about them, but because of the vast content within courses and the artificial barriers separating them, students seldom gain adequate perspective concerning "the way of the scientist" or the relationships between the sciences and the humanities. Moreover, transition to college and later life might well be more effective if students were exposed to a wider spectrum of challenging ideas while still under the careful guidance of high school teachers. A student's views are likely to have little depth unless they are challenged and hence critically examined from time to time. As William Cannon has said:

> Even in religion, we ought to be confronted with ideas with which we violently disagree. One learns far more from reading the works of thinkers who disturb and challenge him than from thinkers who confirm his own opinions. For example, one of the tragedies of pre-war Europe was that the prime minister of Great Britain and the heads of government of the other democracies who had to deal with Adolph Hitler had never read *Mein Kampf*.[1]

Students will venture into such challenges if given the opportunity. In early trials with the discussion unit program, students researched and presented topics of interest to them which occasionally touched upon controversial issues, such as "Science and the Control of Human Behavior," "Science and Religion," and "Science and Warfare." For the class presentations, students responsible for the presentation were expected to have studied the topic in depth and to make their presentations in an unbiased way. When a bias was evident in the presentation, the student was asked to point it out.

The discussion topics were first used as a unit at Enfield High School in June 1966. My college preparatory physics classes worked full time in the unit following their final examinations. Prior to that time individual students studied certain topic areas in depth.

A list of major topics was distributed to all students early in the year. Each interested student was asked to select one topic of interest to him and to investigate it in detail. If he desired, he could review the relevant literature and submit a written report as a means of satisfying one of the two required outside reading assignments which were part of the physics course.

The topics discussed varied from class to class depending upon the interests expressed by the students. Naturally, only a few topics could be discussed at length in each class. Almost all the topics did produce lively discussion. However, those topics in which members of the class were best prepared by prior study produced the most meaningful discussion. Student interest was greatest in the discussions concerning science and its relation to religion and social problems.

To keep interest in the discussions alive and vital, the teacher should vary the method of presentation of different topics. A relevant selection of poetry, a short quotation from an appropriate literary work, or a recording of a pertinent folk song are some of the motivational devices which may be employed.

Discussion can be initiated in a variety of ways. Qualified students might debate an issue in which they express divergent points of view. A student, teacher, or resource person, e.g., a scientist, clergyman, historian, or philosopher, might be asked to make a prepared presentation. When the students are reasonably well versed in the subject, the group leader might pose leading questions for discussion. A student presenting a particularly well-done report might be invited to make his presentation to other classes.

Resource persons from outside the school are particularly helpful in some phases of topic study. Such persons can initiate discussion by presenting background information. They can also meet with the students after they have investigated a particular subject and at that time discuss unresolved issues.

One outgrowth of our use of the discussion unit was the formation of an extracurricular seminar group called "Great Ideas." This group had a nucleus of about eight boys who were students in the science classes where the discussion unit had been presented.

MAJOR topics and subtopics for discussion concerning science and its relation to other disciplines are listed in this section. The subtopics have been selected for their appeal to secondary-school students and also to limit initially the scope of discussion and study for a student. Students may wish to attack a problem which is even more precisely defined than the general subtopic areas listed below. Such limitation of a problem area by a student should, of course, be encouraged so that he may study and review his chosen problem in sufficient depth.

A student selecting the topic "Science and the Federal Government in the USA" might, for example, devote his attention to one question similar to the following: Do scientists now have too little or too much power to determine the path of research which is to be sponsored by federal agencies? Should the government control the use of hallucinogenic drugs, etc.? If so, who should be responsible for such control? A student selecting the topic "Population Growth and Genetics" might devote his attention to one question, such as: Is population and/or genetic control desirable? If so, who is to exercise this control? Students should also be urged to suggest additional topics which are appropriate for study, since the listing of topics here is certainly not exhaustive.

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[1] Cannon, William R. "God Is Not Dead at Emory." A statement released to the press November 30, 1965, on Altizer and the God Is Dead movement. p. 3.

I. Science and Social Problems
  A. Man's Relation to Man
  B. Science and Political Systems
  C. Science and the Federal Government in the USA
  D. Population Growth and Genetics
  E. Effects of Technological Progress on Human Behavior
  F. Population and Poverty
  G. "Control" of Life through Science
II. Science and Technological Development
  A. Science and Warfare
  B. The Nuclear Arms Race
  C. The Race into Space
  D. Food and Fuel Supplies for Tomorrow
  E. Automation
  F. Man and the Computer
  G. Pollution and Waste of Natural Resources
III. Science and Literature
  A. Science and Fiction
  B. The Impact of Science in Literature
  C. Science and the Poet
IV. Science and the Arts
  A. The Impact of Science in Art
  B. Architecture: Science or Art?
  C. Science and Music
  D. Science and Creativity
V. Science and Philosophy
  A. Expanding Conceptions of the Universe
  B. Effects of Scientific Inquiry on Philosophic Thought
VI. Science and Religion
  A. Can Science Prove (or Disprove) the Existence of God?
  B. The Impact of Scientific Thought on Theology
  C. Free Will versus Determinism
  D. Theories of Evolution and Judeo-Christian Belief
  E. Are Scientific and Religious Views Compatible?
VII. Role of the Scientist in Solving the World's Problems
  A. Views of Prominent Contemporary Scientists
  B. Effects of the "Scientific Method" Outside of the Natural Sciences

ALTHOUGH college preparatory science courses are frequently overloaded with large quantities of subject material, some teachers may wish to weave topics such as those given into the fabric of their courses as supplementary material. One class session scheduled for such discussions every month or so might at first appear difficult for a science teacher to justify. When one considers the long-term implications of the issues, however, one class session per month may not appear to be adequate. There is little doubt about the value of such unifying discussions; the problem is finding time to include them in an already crowded course.

In many secondary schools, final examinations are administered two or three weeks before the beginning of the summer recess. In these schools science teachers might well focus class attention on these discussion topics after the examination period. The discussions could provide excellent perspective for the year's work. They should also prove exciting and challenging enough to hold student attention during the final days of the school year.

The topics are also well suited for use in a series of afternoon or evening seminars. Interested students could meet at regular intervals and discuss the issues that concern them. Guest speakers from a wide range of fields might well be invited to meet with the students from time to time.

Some schools may find time in their schedules to program an inter-departmental enrichment course utilizing the discussion topics. Students would benefit from the exchange of views and approaches among teachers specializing in the natural sciences, the social sciences, and the humanities.

THE periodicals listed below have been of special reference value for student research, and they should be available in school libraries.

Bulletin of the Atomic Scientists
Christian Century
Contemporary Civilization
Daedalus
Nation
Saturday Review
Science
Scientific American
UNESCO Courier

The books listed below are of special reference value for teachers:

1. Bronowski, J. *Science and Human Values.* Harper and Brothers, New York. 1959.
2. Gilman, William. *Science—U.S.A.* The Viking Press, New York. 1965.
3. Snow, C. P. *Two Cultures and the Scientific Revolution.* Cambridge University Press, Cambridge, England. 1961.

Folksongs have been helpful in initiating some discussion. Appropriate ones include: "Pollution," "MLF Lullaby," and "Who's Next," recorded on the record *That Was The Year That Was,* Tom Lehrer, Reprise, 6179.

Several films which will stimulate interest in certain topics are available from various distributors. Many of these are on free loan from telephone companies, industry, and government agencies, such as the National Aeronautics and Space Administration and Atomic Energy Commission. Films on pollution can be obtained from many sources, often with emphasis on local regions of the country. The most appropriate film which we used was entitled *Frontiers of the Mind;* it is now distributed by Encyclopaedia Britannica Films, Inc. This film describes current research on the mind, and it touches upon control of human behavior in a very forceful way. □

PART V
RESOURCES FOR CURRICULUM BUILDING

Book reviews and notes about other available materials

General Background

Only One Earth. Barbara Ward and René Dubos. W. W. Norton & Company, Inc., 55 Fifth Ave., New York 10003. 1972. 225pp. $6.

This book, subtitled The Care and Maintenance of a Small Planet, is "an unofficial report commissioned by the Secretary-General of the United Nations Conference on the Human Environment, prepared with the assistance of a 152-member committee of corresponding consultants in 58 countries."

Barbara Ward is as distinguished as a political economist as René Dubos is as a scientist, and both are among the best of our contemporary writers. They are brilliant collaborators in this landmark examination of our environmental situation from a global perspective.

If anyone is looking for a guide to a whole curriculum in interdisciplinary science —or even in human problems of social organization—this book could be it. In broad strokes, the authors sketch the past and paint the picture of our present situation. Over this background they add their own insights as to causes and consequences of social, political, and economic decisions. Finally, they bring the reader to the frontiers of each problem, indicating what must yet be learned on the scientific side and suggesting some alternatives in the probable or possible applications in technology, where "the difficulties will originate not from uncertainty about scientific facts, but from differences in attitudes toward social values." On the economic, social, and political side, their discussions of the developing regions of the planet and the accommodations to be made for "coexistence in the technosphere" are both lucid and compassionate. Many of the disparities in these views were clearly evident in the Stockholm conference.

As the authors state in the introduction: "The establishment of a desirable human environment implies more than the maintenance of ecological equilibrium, the economical management of natural resources, and the control of the forces that threaten biological and mental health. Ideally it requires also that social groups and individuals be provided with the opportunity to develop ways of life and surroundings of their own choice. Man not only survives and functions in his environment, he shapes it and he is shaped by it. As a result of this constant feedback between man and environment, both acquire distinctive characteristics which develop within the laws of nature, yet transcend the blind determinism of natural phenomena. The exciting richness of the human environment results not only from the immense diversity of genetic constitution and of natural phenomena but also and perhaps even more from the endless interplay between natural forces and human will."

But this desirable environment is far from being achieved, and the authors find that "the two worlds of man—the biosphere of his inheritance, the technosphere of his creation—are out of balance, indeed potentially in deep conflict. And man is in the middle."

In their discussions of specific aspects of man and the environment, the authors give special attention to energy needs, sources, and technology; to population, its size and distribution; the planet's underlying systems; pollution and its economic and social costs; use and abuse of the land; pressures on resources; the Green Revolution; and human settlements. Summaries of present situations, often in chart form, are given, along with indications for further research and study.

Finally, in a concluding chapter on Strategies for Survival, the authors recognize that "There are three clear fields in which we can already begin to perceive the direction in which our planetary policies have to go. They match the three separate, powerful and divisive thrusts—of science, of markets, of nations—which have brought us, with such tremendous force, to our present predicament. And they point in the opposite direction—to a deeper and more widely shared knowledge of our environmental unity, to a new sense of partnership and sharing in our sovereign economics and politics, to a wider loyalty which transcends the traditional limited allegiance of tribes and peoples. There are already pointers to these necessities. We have now to make them the new drives and imperatives of our planetary existence. . . .

"A strategy for planet Earth, undergirded by a sense of collective responsibility to discover more about man-environment relations, could well move, then, into operation on these three fronts: atmosphere, oceans, and climate. It is no small undertaking, but quite possibly the very minimum required in defense of the future of the human race."

Only One Earth is one of the year's most important books and should have high priority whether one reads it as a science educator, as a citizen of the twentieth century, or simply as a member of the crew of Spaceship Earth.

Mary E. Hawkins

Man's Impact on the Global Envionment. A report of the Study of Critical Environmental Problems. 319pp. $2.95. Massachusetts Institute of Technology, M.I.T. Press, 50 Ames St., Cambridge, Massachusetts 02142. 1970.

In the past two years, there has been a proliferation of books concerned with man's environmental problems. Most of these books have been interesting or provocative or both, and they have evoked a large amount of action and reaction. Their focus, in general, has been on the nature and extent of the damage man has done to "space ship" earth. Few of these books contain a detailed examination of the kinds of information needed to make long-term plans for the future of our planet. *Man's Impact on the Global Environment* is an exception—the authors go beyond stating the problem and focus prime attention on information requirements for a sound environmental action program.

The authors of this book report the results of a one-month interdisciplinary examination of the global, climatic, and ecological effects of man's activities. Fifty full-time participants including meteorologists, oceanographers, ecologists, chemists, physicists, biologists, geologists, engineers, economists, social scientists, and lawyers examined those environmental problems whose cumulative effects on ecological systems have worldwide significance. The main concern of the group was the effects of pollution on climate, ocean ecology, and large terrestrial ecosystems.

This book should be particularly useful to teachers and students of the environment because of the treatment of information needs, the extensive bibliographies which accompany each section of the book, and the excellent description of the nature of man's environmental problems.

Hans O. Anderson

As We Live and Breathe: The Challenge of Environment. 240pp. $4.65. National Geographic Society, Washington, D.C. 20036. 1971.

The roots of America's environmental problems lie deep in our past. This book traces man's impact on the New World and stresses the adverse effects which resulted from his labor for food, his demands for energy, and his industrial products. It also underscores the compounding of environmental problems by the world's rapidly increasing population.

This is more than just another doomsday book; it also shows the attempts of a growing number of Americans to regain a more livable environment. It discusses the search for nonpolluting forms of transportation, for programs to revive cities, and for methods to recycle garbage into usable resources.

This well-written book has many excellent pictures. It is recommended for anyone interested in the environment, from advanced junior high students to adults.

Donald R. Fowler

Man and Environment. Robert Arvill. 332pp. $1.65. Penguin Books, Inc., 39 West 55th Street, New York 10019. 1970.

A study of the impact of human beings or land, air, water, and wildlife and the environment they create, as studied in England. It also tells about the possibilities man now has to reshape and create a new environment that fits his highest aspirations.

Spaceship Earth, A Space Look at Our Troubled Planet. Don Dwiggens. 80pp. $4.50. Golden Gate Junior Books, Box 398, San Carlos, Calif. 94070. 1970.

The author sets forth the major environmental problems besetting our planet and investigates the technology now being developed to meet the worldwide emergency.

This small book is one of the best collections of material seen in one volume on the subject. Well illustrated; a valuable high school and junior high school source book.

Charles Carpenter

Our Living Land

The Department of the Interior has published its 1971 yearbook, *Our Living Land*. The publication evaluates man's effect on the American landscape and offers alternatives for creating an environment suited to modern needs while still preserving land resources. Full-color pictures and unusual graphics make this a valuable addition for environmental experts as well as laymen.

Our Living Land is available from the Superintendent of Documents, 5801 Tabor Avenue, Philadelphia, Pennsylvania 19120, for $2.

Anthologies and Books of Readings

No Deposit—No Return. Huey D. Johnson. 351pp. $2.95. Addison Wesley Publishing Co., Inc., Reading, Massachusetts 01867. 1970.

This environmental anthology is a collection of 65 position papers from the United States National Commission for UNESCO conference, "Man and His Environment—A View Toward Survival," held in San Francisco in November 1969. Contents include papers on environmental concerns by leaders from the social and physical sciences, government, law, religion, art, education, media, industry, youth, and activist movements.

This text is the new in-depth primer for environmental awareness for all concerned citizens, representing both radical and conservative positions. Informative, easy-to-read, thought provoking, this paperback points out the real need of all citizens for a working knowledge of the social and political sciences.

This book could be used in high school seminars, nonmajor introductory college science courses, in integrated or interdisciplinary liberal arts seminars, or in environmental courses. It can help educate those of the general public who wish to know what is and will be going on in the global environment.

James V. O'Connor

Man, Health and Environment. Brent Q. Hafen, Editor. 269pp. $3.95. Burgess Publishing Company, 426 South Sixth Street, Minneapolis, MN 55415. 1972.

This is an anthology consisting of 31 articles related to environmental health and gleaned from a wide variety of publications. The collection, divided into seven divisions, includes topics related to air pollution, water and solid waste, noise and radiation, toxic substances, population growth, and environmental education. The editor accumulated articles representing a wide range of viewpoints, to help the student and general reader differentiate between allegations which are sound and those which are "patently alarmist and exaggerated." The articles, semitechnical and general in nature, include an abundance of facts and other informational data from which the reader is permitted to draw his own conclusions. The section on air pollution specifically outlines the effects of pollutants on the respiratory system and discusses in some detail the kinds of wastes dumped into the air over the United States. A section prepared by Carl Morgan and titled "Never Do Harm" gives the benefits and risks from medical X-ray, color television, nuclear power, microwave ovens, ultraviolet radiation, lasers, and radioisotopes. An unusual article, "Metallic Menaces," tells of the effects of metals on health. The article suggsts that the fall of the Roman Empire was caused by an overabsorption of lead from pots in which grape juice was boiled in the preparation of wine. The book is recommended for use by especially interested high school students, teachers, and for the college level.

Lorenzo Lisonbee

Environment: Readings for Teachers. J. W. George Ivany. 287pp. $3.50. Addison-Wesley Publishing Company, Inc., Reading MA 01867. 1972.

A collection of environmental essays which are applicable to today's educator—an extremely interesting work. It is not a structured text intending to solve the problems of pollution but aims rather to develop a fundamental insight into the problems of our ecologically minded culture. *Environment: Readings for Teachers* would best be used as a supplemental text for a methods course or as a general reference.

Six main areas of investigation are presented: the environmental crisis, pollution, human ecology, man and radiation, environment and social action, and the relation between environment and education. Each of these units attempts to give the necessary tools for developing a curriculum that is in tune with our troubled times.

Pollution of our environment is the key topic which all of the distinguished authors interject into their essays. Pollution does not merely mean contaminating our environment as we usually understand the definition, but rather includes anything that artificially alters our surroundings for the worse.

Robert Plaia

Man and His Physical Environment. Garry McKenzie and Russell O. Utgard, Editors. 338pp. $4.95. Burgess Publishing Company, 426 South Sixth Street, Minneapolis, MN 55415. 1972.

This is a collection of carefully chosen readings in environmental geology, intended as an introduction to the subject for students taking courses in geology and related fields. The editors selected articles dealing with health and disease, waste disposal, mineral resources, land reclamation, land-use planning and geological hazards—recognizing the fact that environment problems are highly complex and are not confined by academic boundary lines. The classic brief satirical essay by Garrett Hardin titled "Nobody Ever Dies of Over-Population" is one of a number of selections of unique interest, such as "Beneficial Effects of the Alaska Earthquake," "Medical Geology," "Nothing Is Without Poison," "A Nuclear Graveyard," "Disposal of Liquid Waste by Injection Underground," and "Nature, Not Only Man, Degrades Environment." The three appendices include a geological time chart, four pages of mathematical information, and a glossary of selected environmental and geological terms.

Lorenzo Lisonbee

Technology and Social Change. Wilbert E. Moore, Editor. 236pp. $2.45. Quadrangle Books, Inc., 12 E. Delaware Pl., Chicago, IL 60611. 1972.

Moore's *Technology and Social Change* is a skillfully edited collection of articles drawn exclusively from *The New York Times*. Divided into three main parts (The Consequences of Technological Change, The Course of Technological Change: Past and Future, and The Setting of Social Policy), this book attempts to appraise the technological aspects of our modern society and the position of technology with respect to social change, in order to clarify what is meant by technology itself.

Contributors include Arnold Toynbee, Bertrand Russell, J. Bronowski, and others. This book is intended for the general public, especially those interested in the debate between "hard-line" technologists and those humanists who view technology as necessarily destructive of life on earth.

Charles A. Wall

Technology and Society. Noel de Nevers, Editor. 307pp. $3.95. Addison-Wesley Publishing Co., Inc., Reading, MA 01867. 1972.

A collection of readings and discussion questions dealing with problems arising from the interaction of society and technology. *Technology and Society* might serve as a basic resource for introductory engineering courses for technical and nontechnical students. A number of carefully selected articles are suggested as an introduction to the effects of technological change on society, such as "The Complaints About Technology," "History of Technological Change," "How We Respond to Technological Change," the "Interrelations of Technology," and "Science-Technology and Government."

Articles by Rickover, Calder, Hardin, and Newcomb, along with discussion questions concerning the writings of Huxley, White, McLuhan, Ehrlich, Nader, and Snow, provide the student with an interesting collection of philosophical readings on the topic.

Charles A. Wall

Man and the Ecosphere: Readings from Scientific American. 307pp. $11; $5.75, paper. W. H. Freeman and Co., 660 Market Street, San Francisco, Calif. 94104.

This volume is another compilation of articles which previously appeared in *Scientific American*. The type size and illustrations are as they originally appeared.

The theme which binds the various articles together is subdivided into four major sections: The Ecosphere and Pre-Industrial Man, Limits Rarely Perceived, The Dimensions of Intervention, and Management and Buying Time. The substance of sections 1 and 4 is fairly obvious. The somewhat more cryptic sections 2 and 3 deal respectively with population-resource problems and pollution problems.

Recommended for junior or high school students and teachers as a supplementary source of information.

Robert Menefee

OTHER BOOKS OF INTEREST

Leaders in American Conservation. Henry Clepper. 353pp. $10. Ronald Press Co., 79 Madison Ave., New York 10016. 1971.

Concise biographies of 360 men and women who have "made noteworthy contributions to the country's natural heritage over the past 100 years."

Environmental Science Resource Lab. (The ECO-LAB) Herbert T. Megorden and Howard D. Peet, Editors. $97.50. Library Services Division, Box 128, Barnesville, MN 56514. 1972.

A collection of 150 articles, reports, and essays on ecology and the environment divided into: Part I, Quality of the Environment; Part II, Hydrology; Part III, The Atmosphere. Designed and organized to provide "instant access to current thinking and developments in the environmental sciences." Reprints are from many authentic sources. Each part is boxed separately with index. For high school.

Glenn O. Blough

Environmental Education

Teaching for Survival. Mark Terry. 240pp. $1.25. Ballantine Books, Inc., 101 Fifth Avenue, New York 10003. 1971.

Teaching for Survival is not a typical book; it is neither a methods text nor a content book. It does contain both content and ideas for approaches, in one sense, but it does much more. Terry criticizes the content, the approaches, and the curricula of schools past and suggests some specific new directions and concrete ways to follow these new approaches.

Part One of the book provides an attack upon the past and points to the future with respect to environmental education. It ends with a precise and complete statement of objectives of environmental education. Part Two considers the classroom, school, and district and how each can consider environmental problems. Terry does not mention subjects or curriculum. Instead he emphasizes philosophies, policies, and activities suitable to a variety of situations and at varying age levels. There are no step-by-step procedures advanced since the author expects teachers to plan their own approaches through their own ingenuity and experience. Terry urges teachers "to plan your own environmental questions, and act on your own environmental ethic."

Part Three is entitled "The Subject Matters." It illustrates how "ecology" can and should be a part of every subject matter. Suggestions are made as to how certain activities in various courses can promote deeper study of both the subject and the environment. Subjects are classified into observers, interpreters, and users.

The book is highly recommended as a "must" for schools and teachers who are trying to move into a program of environmental education. The cautions and the suggestions for change are many. The philosophy is refreshing. Certainly if Terry's words are read carefully, the many attempts in the area of curriculum development in environmental education will be more than a current "passing-fad."

Robert E. Yager
University of Iowa
Iowa City

All Around You—An Environmental Study Guide. Study guides with workbook space for students to use in answering questions or writing in their own observations and ideas and with accompanying teacher's pages. Main sections are Awareness, the Urban Ecosystem, Nature's Ecosystem. Copies may be reproduced for class use. Prepared by the Bureau of Land Management, United States Department of the Interior. Order from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402; $1.50.

Pollution Analysis by Optical Microscopy. A 24-page guide to recommended ways and means of using optical microscopy for the detection and measurement of pollutants in air, water, and food products. Outlines use of techniques such as polarization, phase-dispersion staining, fluorescence microscopy, and photomicrography. Free copies of this guide (no. 31-2400) may be obtained by writing: Bausch & Lomb, Scientific Instrument Division, Dept. 6606, 635 St. Paul St., Rochester, NY 14602.

Adventures on the Beach, Teachers' Guide for Grades K-12. Produced by The Environmental Resource Council and published by the Board of Education of the City of New York, this publication is designed to help teachers utilize the Atlantic seaboard as an outdoor science laboratory.

New York City public schools should order copies from the Bureau of Supplies (no. 00-8062-70). Outside agencies may purchase the 104-page publication from: Board of Education of the City of New York, Publications Sales Office, 110 Livingston St., NY 11201; $2.50. Make checks payable to Auditor, Board of Education.

The Millipore Corporation has introduced a new miniperiodical, *Millipore Technology in Environmental Education*, which will be presenting practical solutions to frequently encountered problems in environmental study. The publication will be sent without charge to *TST* readers. Write to Millipore Corporation, Bedford, MA 01730.

The Do-It-Yourself Environmental Handbook, prepared by the Dayton Museum of Natural History, is a practical handbook for individual action on many problems of environmental clean-up and preservation. Order from Dayton Museum of Natural History, 2629 Ridge Ave., Dayton, OH 45414. $1.95 per copy.

Your Environment: Air, Air Pollution and Weather. Collins M. Henson. 206pp. $4.95. The Interstate, Printers and Publishers, 19-27 N. Jackson St., Danville, Il. 61832. 1971.

Written for junior high school students or for students in lower-level senior high, this book contains approximately 39 student activities, most of which have been in general science textbooks for years and only two of which deal directly with the problem of air pollution. Although a promotional announcement concerning the book uses the terminology of "scientific inquiry," the student investigations are designed to illustrate a principle or concept rather than to promote independent student inquiry. Nevertheless, this book could serve as a resource for a teacher who is willing to restructure the material into a more inquiry-oriented format.

Patricia E. Blosser

EP—The New Conservation. Charles J. Griffith, Edward Landin, and Karen Jostad. 184pp. $1.25 paper. The Izaak Walton League of America, Suite 806, 800 N. Kent St., Arlington, VA 22209. 1971.

EP is Environmental Practice and EE is Environmental Education, and neither is nature study nor outdoor education. "Learning to make environmentally intelligent decisions is the heart and soul of environmental education." ". . . environmental practice (EP) is essentially a method of causing environmental education or action to occur by use of models or examples." The authors proceed to furnish dozens of "models or examples," real and imaginary, to aid the citizen to further the cause of "the new conservation." Schools and school teachers are involved in the discussion, of course, but so is the part that clubs, the individual, the community, and the government may play. Realistically, it is pointed out that only a minority care enough to get things done. In fact, perhaps the most significant statement to apply to this tract is that it is realistic. Among the models and examples are many which will strike a given reader as trivial, but another reader will be aided by those same suggestions. About one-fourth of the book is used to list source materials, sample questionnaires, reading lists, and the like. Unfortunately, there is no index. Appropriate for junior and senior high school.

Richard M. Whitney

Environmental Study

Places for Environmental Education, a 10-page report, from Educational Facilities Laboratories, is a synthesis of a conference held at the Smithsonian Institution's Belmont Center. The booklet suggests the use of specific strategies and facilities to achieve the most effective approach to environmental study.

For free single copies, contact Educational Facilities Laboratories, 477 Madison Avenue, New York, N.Y. 10022. Multiple copies: 25 cents each.

Junior High Course on Environmental Problems and Solutions

A course which teaches junior high students about environmental problems and solutions is now available from The Creative Teacher, Inc., Box 5187, Grand Central Station, New York, N.Y. 10017. This 15- to 20-hour course emphasizes recycling and stimulates students to participate in community efforts aimed at improving the environment.

Called *Environmental Action: Recycling Resources*, the course retails for $25 plus shipping. It includes a Teacher's Manual, Student Handbook, two color filmstrips, record (containing sound tracks for both filmstrips), and a class simulation game called "Ecopolis." Additional Student Handbooks are available at 35 cents each.

Congressional Testimony on Environmental Education

The Environmental Problem presents selections from hearings on the Environmental Education Act of 1970. The selections include portions of testimony from 45 witnesses before the Select Subcommittee on Education of the House of Representatives, representing about one-third of all the testimony heard. The witnesses, including LaMont Cole, Garrett De Bell, James E. Allen, and Margaret Mead, explored ideas on how the vehicle of education might be employed in improving the quality of the environment. *The Environmental Problem,* edited by Irving Morrissett and Karen B. Wiley, may be purchased from Social Science Education Consortium, Inc., 855 Broadway, Boulder, Colo. 80302. Publication no. 140. Paper $6.95; hardcover, $8.95.

Environmental Education Program

Under the authority of the Environmental Education Act of 1970 the Office of Environmental Education is supporting a wide variety of projects and activities. A description of representative projects and of how 1971 grants were made is presented in a 14-page booklet, *The New Environmental Education Program of the U.S. Office of Education*. It is available from: Superintendent of Documents, U.S. Government Printing Office, Washington, D. C. 20402; 30 cents.

Conservation and Environmental Education in the Western States. A Status Report on State-level Programs Conducted by Departments of Education and Resource Management Agencies. This report was prepared as a part of the Western Regional Environmental Education Project, coordinated by the California Department of Education, to provide baseline data on environmental education in the region at the start of a three-year project funded through ESEA Title V. It includes information on number of state consultants, resources agencies, state laws, state publications, special funds for environmental education, and other topics. The project director is Rudolph J. H. Schafer, 721 Capitol Mall, Sacramento, CA 95814.

Yellow Pages of Learning Resources is concerned with the potential of the city as a place for learning. It contains a selection of typical firsthand learning resources that can be found in almost any city and outlines the avenues to follow in order to make these resources accessible. Copies of the 94-page book are available from The MIT Press, Massachusetts Institute of Technology, Cambridge, MA 02142; $1.95.

Action Programs

Environmental Conservation

Help! Give Earth A Chance by Holt Bodinson and Sandy Marvinney gives specific recommendations for individualized action in preserving the environment. The 28-page booklet offers concrete measures to curtail air, water, and noise pollution; preserve land and wildlife; and help control population. Resources for further information on these topics are also included.

For free single copies of the booklet write to *Help*, New York State Department of Environmental Conservation, 50 Wolf Road, Albany, New York 12201.

"Pick Up The Pieces," an instructor's manual by Keep America Beautiful, Inc., suggests litter prevention and other pollution control projects for high school students. As long as the supply lasts, copies are available for 20 cents each from Keep America Beautiful, Inc., 99 Park Avenue, New York, N.Y. 10016.

Toward a New Environmental Ethic, published by the U.S. Environmental Protection Agency, summarizes goals and government programs on environmental questions. Copies are available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402; 60 cents per copy.

Can Recycling. The Can People (American, Continental, National, and The Heekin can companies) offer several pieces of material to aid groups interested in organizing a citizens committee for community action to recycle the can. Materials and prices are: "Recycling the Can in the Seventies," "The Recyclers Handbook," both free; Bus Card, 10 cents; Poster, 5 cents; Bumper Sticker, 10 cents. Order, enclosing payment, from The Can People, G.P.O. Box 2682, New York, N.Y. 10001.

The National Audubon Society has expanded its services for aiding other organizations to establish their own environmental education centers so that it now has another planning expert and a program for small natural areas (under 50 acres). The Society offers its professional field services on a cost-shared basis. It also issues a quarterly newsletter for nature centers and environmental educators, leaflets, manual, lectures, and a film. Address inquiries to the Nature Center Planning Division, National Audubon Society, 950 Third Ave., New York, NY 10022.

Bibliographies and Reference Lists

Science for Society: A Bibliography, Third Edition, covers science, technology, society, resources and the environment, education, health, and conflict and population. Prepared for students, teachers, and laymen. Published by the American Association for the Advancement of Science, 1515 Massachusetts Ave., N.W., Washington, DC 20005; $1 per copy.

An environmental book list of significant environmental books published in 1971 is available at no cost to librarians and instructors from Environment Information Center, Inc., 124 E. 39th St., New York, NY 10016. Enclose 25 cents for postage and handling.

Environment Information ACCESS is an extensive semimonthly printout of titles and abstracts of material, both published and nonprint, in the area of environment. The cost of an annual subscription is $150. Also available is **The Environment Index 1972,** a reader's guide to more than 60,000 entries in 800 pages. Price per copy $75. Both are published by Environment Information Center, Inc., 124 East 39th St., New York, NY 10016.

The AAAS Science Book List. Third Edition. Compiled by Hilary J. Deason. 440pp. $9. AAAS Publications, 1515 Massachusetts Ave., N.W., Washington, D.C. 20005. 1970.

An extensive listing of 2,441 titles consisting of author, title, publisher, price, descriptive annotations, and Library of Congress card number.

Educators Guide to Free Films. 789pp. $10.75. **Educators Guide to Free Tapes, Scripts, and Transcriptions.** 183pp. $7.75. **Educators Guide to Free Filmstrips.** 162pp. $8.50. **Educators Guide to Free Science Materials (A Multi-Media Guide).** 367pp. $9.25. Educators Progress Service, Inc., Randolph, Wis. 53956.

Annual revision of the popular and useful series.

Special Subjects:

ECOLOGY

Ecology: Man's Relationship to His Environment. Lawrence J. Pauline and Howard Weishaus. 211pp. $2, paperback. Oxford Book Co., Inc., 387 Park Ave. S., New York 10016.

This paperback offers an informed look at man's interrelation with his environment. It considers scientific principles from a sociological standpoint and with a view to man's future survival. The use of case studies and mini-reports is effective and adds much to the total presentation.

Intended for use as a textbook at the secondary or junior college level, the book is inclusive and easy to understand. But it is a generalized account and has all the shortcomings of the typical textbook. It does not suggest actions; it merely describes problems and often makes emotional appeals. Its greatest weakness is the failure to cite references for data and for future prophesies.

ROBERT E. YAGER

Fundamental Ecology. Arthur S. Boughery. 222pp. $3.95. International Textbook Company, Box 30, Scranton, Pa. 18515. 1971.

This is the first book in a series of eight planned books on ecology and environmental confrontation. The author is also editor of the series. As is usually true of the introductory book in a series, this one serves as an overview and introduces the books that follow. The contents include ecosystems, environments, population aspects (dynamics, evolution, interaction, and behavior), and communities. Some parts of the book read like a brief encyclopedia of ecological terms—certainly few have been omitted.

As a brief, concise overview of ecology, this book could serve quite well, for the references at the ends of the chapters suggest further readings. Having used R. L. Smith's book, *Ecology and Field Biology* in our classes, we were interested to note that at least five pages of illustrations were borrowed and credited to the author, yet his name and book were not mentioned once in the bibliographies. This book is intended for introductory college classes in college ecology.

M. F. VESSEL

Ecology: Science of Survival. Laurence Pringle. 152pp. $4.95. The Macmillan Company, 866 Third Ave., New York 10022. 1971.

Ecology: Science of Survival covers: webs in nature, living parts of ecosystems, major biomes of the world, flow of energy, biogeochemical cycles, changes in nature, patterns in population growth, and man's role in each of the above. The author presents a sensible and accurate picture of ecology. The book would serve as a good introduction to the subject at the junior high level.

ZINA GREENE

What's Ecology? Clifford C. Humphrey and Robert G. Evans. 60pp. $2.95. Hubbard Scientific Co., P.O. Box 105, Northbrook, Ill. 60062. 1971.

Chapters deal with principles of ecology, brief descriptions of major ecological systems, energy sources, problems and interactions, man and the biosphere, and the cultural response to ecology. The book is concisely written and contains considerable information and several excellent illustrations. The authors succeed in presenting an acceptable definition of ecology, but they fail to portray ecology as the exciting, dynamic search for an understanding of man and the biosphere. Useful for secondary school students or adults interested in a survey of the nature of ecology.

HANS O. ANDERSEN

Everybody's Ecology. Clay Schoenfeld. 316pp. $7.95. A. S. Barnes & Co., Inc., Box 421, Cranbury, N.J. 08512. 1971.

The book is recommended for all who need a guide to understanding nature, who desire an improved perception of the meaning of ecology, and who are interested in practices and policies that can enhance the future of the out-of-doors. It includes the basic principles of ecology, a guide to understanding and appreciating nature, and suggestions for citizen action in environmental management.

Recommended for school library use and for adults who desire a fresh, lively, and stimulating introduction to environmental problems.

ROBERT E. YAGER

Ecology: Man's Effect on His Environment and Its Mechanisms. John Hoke. 96pp. $3.75. Franklin Watts, Inc., 845 Third Ave., New York 10022. 1971.

Provides a concise introduction to ecological concepts appropriate for the junior high and high school level. The vocabulary and the sentence structure used also require 14- to 18-year-old reader maturity. The second half of the book concerns man and some of the problems that have resulted from his technological manipulations of the environment. Attitudinal and behavioral change is cited as crucial to improvement of the human environment, and the author stresses the importance of knowledge of ecological principles for achieving this change.

A. L. BRASWELL

Before Nature Dies. Jean Dorst. 352pp. $2.45. Penguin Books, Inc., 39 W. 55 St., New York 10019.

A good source book for junior or senior high school students doing research on the effects of man on nature. It begins with an interesting history of man the hunter, the shepherd, and the farmer and discusses the impact of various civilizations on the earth. Present-day problems of population, erosion, pesticides, pollution, extinction of species, and exploitation of marine resources are a few of the topics which round out this very good study.

BARNEY PARKER

Guardians of Tomorrow: Pioneers in Ecology. S. Carl Hirsch. 192pp. $4.53. The Viking Press, 625 Madison Ave., New York 10022. 1971.

The author describes the circumstances which led eight Americans to dedicate their lives to the preservation of man's surroundings. Thoreau raised a rousing cry in the 1850's for "men to awake, to take a look at themselves and their world." Pinchot and Muir were pioneers in the conservation movement at the turn of the century. In our own time, Rachel Carson intensively probed the use of pesticides and anticipated the prospect of a "silent spring." In addition, the reader is introduced to George Perkins Marsh, known as the father of ecology; to Frederick Law Olmsted, who planned Central Park in New York City; to George Norris of the Tennessee Valley Authority; and to Aldo Leopold, whose concern for the vanishing wilderness led to the establishment of America's first such national region.

A companion volume to the author's *The Living Community*, this book will provide interesting supplementary reading for ecology courses from junior high school through the eleventh grade.

BARBARA M. BENNING

Symbiosis. Thomas C. Cheng. 250pp. $6.95. Pegasus, 850 Third Ave., New York 10022. 1970.

Books for high school students on symbiosis are rare. But for a generation of students interested in togetherness and a generation of science teachers interested in the interrelatedness of nature, symbiosis is a natural.

The book begins with a brief history of research, followed by a discussion of the various forms of symbiosis. There is, naturally, a discussion of the interrelationships between the various hosts and their symbionts, including such topics as methods of contacting and entering, defense mechanisms, and utilizing nutrients. There is a very good chapter on symbiosis and human welfare.

The treatment is scholarly and complete. There is an adequate recommended reading list. The author's preface and the jacket, however, overestimate the reading ability of the audience. The book is suitable only for a very proficient high school biology student or a well-read layman. Nevertheless, the author should be commended for bringing this subject to the high school audience.

THOMAS C. CHENG

ENERGY AND POWER

Nuclear Power Plant Siting: A Handbook for the Layman, published by the University of Rhode Island, explains how power plants work, the pollution aspects of power production, plant safety, and siting concepts, and includes a list of readings. May be obtained from Marine Advisory Service, University of Rhode Island, Narragansett Bay Campus, Narragansett, RI 02882.

Energy and Power. Albert Hinkelbein. 128pp. $4.95. Franklin Watts, 845 Third Ave., New York 10022. 1971.

The book conducts the reader on an interesting, superbly illustrated journey through the various forms of energy, their discovery and eventual harnessing by technology into something usable. Ancient and interesting historical vignettes are interspersed throughout the general treatment of the topic. Current problems relating to waste energy are also discussed.

A very human book, it emphasizes the small and seemingly insignificant discoveries that were the very basis of entire fields of technology and further scientific study. It is rich in historical treatment and recognition of individuals normally not even mentioned in general readings. Highly recommended.

Dale M. Bunsen

Energy and Power. (A *Scientific American* Book) 144pp. $6.50 cloth; $3.25 paper. W. H. Freeman and Co., 660 Market St., San Francisco, CA 94104. 1971.

The people of the United States, according to the foreword of this book, have doubled their consumption of energy every decade of the twentieth century. As any student of arithmetic knows, the last term in such series always exceeds the cumulative total of all the preceding terms. Thus, according to the thesis of this book, more energy will be used in the 70s than in all other decades of the twentieth century combined.

Such is the problem proposed by this work, and it is an excellent one for high school students to consider. But there is a second energy problem confronting society which is equally as serious as the energy-source problem—the need of energy sinks. Heat pollution of the atmosphere by electrical power stations and other huge heat-radiating sources presently faces society. Not altogether facetious is the prediction that by the year 2100 the earth will be radiating into space as much heat from fossil and nuclear fuels as it receives from the sun.

The book consists of articles which first appeared in the September 1971 *Scientific American.* It treats the field of energy and power from the production of natural gas by the countries of the world through such topics as energy required in gardening and energy conversion to a concluding essay on decision making in the production of power. The book is well illustrated with photographs, maps, charts, and abundant graphs.

Secondary school classes in social science as well as natural science will find use for this publication. But the reading and comprehension level of the material is well above the "average" secondary school student. This is a resource book which will find its greatest pedagogical use in inquiry-centered classes after a problem has been clearly identified.

John W. Renner

POLLUTION AND WASTE DISPOSAL

Now or Never: The Fight Against Pollution. D. S. Halacy, Jr. 208pp. $5.62. Four Winds Press, 50 W. 44 St., New York 10036. 1971.

Now or Never presents an absorbing, fact-filled summary of the fight against pollution. The author, while pointing out that nature must shoulder the blame for much pollution, reminds us that "man, the master polluter" has upset nature's healing balance. He examines the problems of air and water pollution, mountains of waste, dangerous pesticides, radioactivity, and noise and discusses some possible solutions. Practical suggestions for individual, group, and institutional action are given, and a list of concerned organizations and useful publications is provided.

Barbara M. Benning

Our Polluted World: Can Man Survive? John Perry. 237pp. $5.95. Franklin Watts, Inc., 845 Third Ave., New York 10022. 1972.

A revised edition of a rambling, but interesting, book first published in 1967. Though the topics range widely, greatest emphasis is on air and water pollution, their causes and effects. High school students and lay persons will find the book of interest. The index is adequate.

Ted F. Andrews

Biology and Water Pollution Control. Charles E. Warren. 434pp. $11. W. B. Saunders Co., W. Washington Square, Philadelphia, Pa. 19105. 1971.

The aim of this book, according to the author, is "to explain the biology that is relevant to water pollution control." Sections include: Conditions of Life in the Aquatic Environment, Morphology and Physiology, Ecology of the Individual Organism, Population Ecology, and Community Ecology.

The author succeeds in writing a text of considerable depth that will give an excellent background to a person interested in the biology necessary for water pollution control. It is a scholarly book, yet is not so detailed that a nonscientist would have difficulty reading it. The literature cited is quite complete. Recommended for students with a good background in biology and chemistry.

Arthur E. Rondeau

The Town That Launders Its Water. Leonard A. Stevens. 122pp. $4.49. Coward, McCann, and Geoghegan, Inc., 200 Madison Ave., New York 10016. 1971.

This is the story of how Santee, a southern California town, solved a serious water-shortage problem. Santee is situated in an area which receives only ten inches of rainfall per year. Its water table had been dropping rapidly, forcing inhabitants to abandon many farms. But community leaders, with the assistance of technical consultants, developed methods for cleaning and recycling sewage water for irrigation and recreational purposes. The "laundered" water now fills eight man-made lakes, providing recreational fishing, boating, and swimming as well as water for farms.

The author writes his story with journalistic flare, telling how a site was chosen and a cleaning plant set up, how federal and state funds were obtained for research, and what psychology was used to gain full public acceptance of the lake water.

The book will have wide reader appeal, especially to high school groups. It is well illustrated with photographs and line drawings.

Lorenzo Lisonbee

Purity or Pollution: The Struggle for Water. Pierre Rondiere. 128pp. $4.95. Franklin Watts, Inc., 845 Third Ave., New York 10022. 1971.

Water is variously seen from a cultural, chemical, geographic, economic, and ultimately a human-survival perspective. Although produced in England, the book provides a cosmopolitan view, presenting an appropriate worldwide photographic sampling. The vocabulary is ninth grade, and the concepts range from junior high upward. An excellent integration of science and social studies.

A. L. Braswell

Getting Down to Earth (an environmental handbook). Attempts to define causes of pollution, indicate effects on environment, examine costs, and suggest solutions to the problems of solid waste disposal and air and water pollution. Well presented and beautifully illustrated. Public Relations Department, Bank of America, P.O. Box 37000, Rincon Annex, San Francisco, CA 94137; $1.

Environmental Pollution

A 19-page annotated bibliography of selected references in *Environmental Pollution* by Michele S. and Daniel H. Stern is available from Michele S. Stern, Department of Biology, University of Missouri, Kansas City, Missouri 64110; 25 cents each.

National Policy on Ocean Dumping Proposed

Ocean Dumping, A National Policy is a report to the President, prepared by the Council on Environmental Quality, chaired by Russell E. Train.

The Council recommends comprehensive legislation to control all ocean dumping. The policy would generally call for banning new sources of ocean dumping and phasing out existing sources. The administrator of the Environmental Protection Agency would be given authority for the issuance of permits to implement this policy.

The report is for sale at 55 cents per copy by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

Lead Hazards

"Health Hazards of Lead," a summary and analysis of relevant medical and scientific evidence, prepared by the Environmental Protection Agency, outlines the health hazards of airborne lead. It includes sections on sources, ambient air levels, levels in water and food, environmental cycling, and human health implications. Copies of the report are available from the Publications Section, Environmental Protection Agency, 5600 Fishers Lane, Room 18B-08, Rockville, Md. 20852. In the *Federal Register* of February 23, 1972 (Vol. 37, No. 36, Part III) the EPA published its Notice of Proposed Rule Making on the Regulation of Fuels and Fuel Additives, which calls for lead-free and phosphorus-free gasoline by July 1, 1974

POPULATION AND FOOD SUPPLY

Rapid Population Growth: Consequences and Policy Implications. National Academy of Sciences. 105pp. $2.45. The Johns Hopkins Press, Baltimore, Md. 21218. 1971.

Follows two earlier publications by the Academy: *The Growth of World Population* (1963) and *The Growth of U.S. Population* (1965). A definition and description of the problems resulting from today's unprecedented rates of human population increase.

The Proceedings of the National Conference on Population Education, convened by the Population Reference Bureau, Inc., November 1971. Assesses the current status of developments in the field, identifies areas of disagreement and those of consensus among various groups, and clarifies opportunities for expanded action. Population Reference Bureau, Inc., 1755 Massachusetts Ave., Washington, D. C. 20036. $1.

Feast and Famine. D. S. Halacy, Jr. 162pp. $4.95. Macrae Smith Co., 225 S. 15 St., Philadelphia, PA 19102. 1971

Excellent supplementary reading at the secondary school level when nutrition, digestion, agriculture, and population problems are being discussed.

The first half of the book reviews in clear, concise prose such topics as food chains, alimentary canal, digestion, classes of foods, vitamins, and so on. The second half becomes a good deal more interesting. It treats the problems of raising enough of the right kinds of food for a burgeoning world population. The final chapter on what is being done to increase food production and on the implications of increased agricultural technology paired with exploding populations makes interesting and thought-provoking reading.

George C. Turner

RESOURCES

Natural Resource Conservation: An Ecological Approach. Oliver S. Owen. 593pp. $9.95. The Macmillan Co., 866 Third Ave., New York 10022. 1971.

This important and useful new textbook fills a vacant niche. It encompasses such fundamentals as soil formation, energy relations, and the hydrologic cycle, basic principles of ecology, and methods of managing soils, water, forests, and wildlife. It includes material on environmental pollution and methods of pollution abatement, as well as a chapter on the human population problem. The title of the final chapter is "Politics, Education, and Survival."

Because of heavy overlapping, the book is an alternative rather than a supplement to a standard ecology text. Students and teachers are likely to welcome its linking of principles with current realities. It retains much of the classical approach, yet joins this with quotations from such activists as Barry Commoner. Each chapter is supported by an extensive bibliography.

A book with such broad range cannot escape faults. In this case there is unevenness in the author's handling of the many proposed and hypothetical solutions to environmental problems. Some are balanced by critical rebuttal, but others are offered uncritically, despite the evidence against them. The author appears to give favorable treatment to several projects that horrify most environmentalists. Compressing so much material into one volume has resulted in inadequate discussion of some topics, such as grasslands and grazing.

Wisely, the author has limited the scope to the resources and ecology of the coterminous United States.

John Perry

Conserving America's Resources. Ruben L. Parsons and Associates. 608pp. $11.95. Prentice-Hall, Inc., Englewood Cliffs, NJ 07632. 1972.

The third edition of a comprehensive source on the subject of conservation, updated in every respect.

Our Natural Resources. Third Edition. P. E. McNall and Harry Kricher. 296pp. $4.95. Interstate Printers and Publishers, 19 - 27 N. Jackson Street, Danville, Illinois 61832. 1970.

A useful guide to resource use and principles of ecology. The new edition reflects the concern for protecting the environment and includes a new chapter on air pollution.

The Water Lords. James Fallows. 294pp. $7.95. Grossman Publishers, Inc., 44 W. 56 St., New York 10019. 1971.

One of a series of study group reports completed by Ralph Nader's staff, which concentrates on environmental pollution as exemplified by the Savannah River situation. Both the city of Savannah and its industries contribute to the pollution problem. Nader's study group advocates that vigorous state and local action be taken to remedy the situation and emphasizes the fact that the situation is not unique to Savannah, Georgia, but holds elements in common with other large industrial cities. This volume should be a satisfactory addition to supplementary reading for a course, or a unit, in environmental education at the high school level.

Patricia Blosser

TRANSPORTATION

How Will We Move All the People: Transportation for Tomorrow's World. Sterling McLeod. 176pp. $4.29. Julian Messner, 1 W. 39 St., New York 10018. 1971.

A good-quality popular science account of the important and bewildering problem of transportation. Examples of the most up-to-date transportation systems and prototypes of transportation vehicles are illustrated and described. There are eight chapters, an index, and many references. A useful reference for elementary science teachers and for junior and senior high school students.

Ted F. Andrews

Audiovisual Aids

The Aging of Lakes. This short color film emphasizes the effect of an increase of dissolved nutrients on a lake. The effect, along with sedimentation, results in the aging of a lake to become successively a bog, meadow, and perhaps a forest. This aging process, called eutrophication, involves many undesirable side effects such as algal blooms and low oxygen levels, which are illustrated.

The accelerating effect of increasing human populations on eutrophication through sewage input is illustrated. Various methods of treating the symptoms of eutrophication are shown. These include dredging, weed cutting, emptying, artificial aeration, and use of plastic sheeting. It is emphasized that these activities treat symptoms not causes. The causes must be treated through changes in sewage treatment. Such changes are shown at Seattle's Lake Washington. Thermal pollution from nuclear power stations is very briefly mentioned.

The film is somewhat superficial; hence its use will probably require the provision of considerable supplementary information by the teacher. Describes the problem well. For general science groups. 14 min. $167.50, color. 1971. Encyclopaedia Britannica Educational Corporation, 425 N. Michigan Ave., Chicago, IL 60611.

Robert W. Menefee

Noise—Polluting the Environment. Good color photography and dramatic sound reproduction of typical annoying home and urban noises. Impressive pre- and post-audiometry of the effects of a hard rock rehearsal on the hearing of the instrumentalists revealed a 25 to 30 percent temporary hearing loss. Extensive treatment of aircraft noises, showing the moving of an entire neighborhood and the abandonment of two schools in the proximity of the Los Angeles Airport. Appropriate for junior high school students to adults. 15 min. $200, color. 1971. Encyclopaedia Britannica Educational Corporation, 425 N. Michigan Ave., Chicago, IL 60611.

A. L. Braswell

Web of Life: Endless Chain. The film shows natural desert scenes of the Arid Lands Experimental Preserve, with breathtaking landscapes, colorful sunsets, plant and animal life, and several suspense-filled predator-prey episodes. Atomic Energy Commission personnel are viewed carrying out many different investigations in their survey of this region.

The absence of narration and the use of appropriate music encourage the viewer to supply his own interpretation to aspects of the film. In the hands of a skillful, nondirective teacher, this film could be unusually effective. Viewers of all ages can derive much enjoyment and benefit from it. 28 min. Color. 1972. Free on loan from Atomic Energy Commission, Washington, D.C. 20545, or available for purchase for $75 from National Audiovisual Center, Washington, D.C. 20409.

Al Braswell

Keys to Basic Ecology: (1) Adaptation; (2 Diversity in Nature; (3) Interrelationship of Natural Things. Each of the three kits contains six full-color filmstrips and 3 LP records accompanied by a script and discussion guide. Designed for intermediate grades. Curriculum oriented. Wide range of problems, appealing to students in various sections of the country. Each set, $54; complete series, $150. Winchester Press, 460 Park Ave., New York 10022. 1971.

Glenn O. Blough

Singer, "America's Urban Crisis." Group 1. This package of six filmstrips with accompanying narration on 33⅓ rpm phonograph records is devoted to the environmental aspects of the degradation of American cities. The topics presented include: air pollution, water pollution, solid wastes, transportation, and housing.

Each tape is accompanied by a teacher's guide which contains the narrative script and a list of purposes. The set is worthy of consideration by teachers at the intermediate or secondary level who are looking for environmental educational materials. $51.50 set (6 filmstrips, 3 records) or $57.50 set (6 filmstrips, cassettes). 1971. Society for Visual Education, 1345 Diversey Pkwy., Chicago, Ill. 60614.

Robert W. Menefee

Ecological Systems—Antarctica. Antarctic scenery and frolicking penguins dominate this well-photographed color film. The ecological concept of "ecotone" provides the basis for an examination of the life associated with the sea-land interface. The "Adelie penguin" is the index animal. Much of the film is devoted to its behavior, nesting habits, and care of offspring. The film stresses the interrelationships of the penguin life cycle, weather, solar radiation, and plant proliferation in the sea.

Other organisms presented include lichens and mosses, the gull-like Skua, and sea elephants. Some very important ecological concepts are mentioned in passing. Overcrowding, population balance, stress in the ecological system, and adaptation are discussed, but not in great depth.

The approach to ecology is descriptive rather than quantitative. This fact and a lack of difficult terminology make the film suitable for junior high school audiences. It is also recommended for senior high school classes, with a suggestion that the teacher include the quantitative aspects of ecology. 13 min. Color, $160. 1971. Aims Instructional Media Service, P.O. Box 1010, Hollywood, Calif. 90028.

Robert W. Menefee

Spaceship Earth. A record album which dramatizes the environmental movement. Includes songs by Pete Seeger, dramatic vignettes of American life, and straight talk from people such as the late Adlai Stevenson, Hubert Humphrey, Paul Ehrlich, and U Thant. The album and accompanying discussion guide are available for $5.95 from Addison-Wesley Publishing Co., 2725 Sand Hill Rd., Menlo Park, CA 94025.

The Oceanography Chart, $3.50; **The Air Pollution Chart,** $2; **The Water Pollution Chart,** $2.50. Full-color wall charts based on the latest scientific facts and compiled by specialists in each of the fields. Roy G. Scarfo, Inc., P.O. Box 217, Thorndale, PA 19372.

Photo Display Available

Kodak is offering a set of 12 color and black-and-white enlargements of photos from its booklet, *Improve Your Environment . . . Fight Pollution with Pictures*. The set is called the "Clean the Scene" Photo Display and is available for $1.

The booklet is also $1; the following discounts are available on this publication: 2-9 copies, 75 cents; 10 or more copies, 50 cents. Kodak suggests that money can be raised by environmental clubs if they buy 10 or more booklets at 50 cents each and sell them at the $1 price. Eastman Kodak Company, 343 State St., Dept. 454, Rochester, New York 14650.

Film Catalog

A newly revised catalog containing more than 9,000 educational films on a wide variety of topics, published by the Mountain Plains Educational Media Council, is offered to educators and organizations needing films for educational purposes. The publication is free of charge. Cataloged films are available for rent from film libraries housed at the Universities of Colorado, Nevada, Utah, or Wyoming. Prices start at $3 for black-and-white films up to 11 minutes in length.

Copies of the catalog may be obtained from Mr. Jack Prince, Bureau of Audio Visual Instruction, University of Colorado, 348 Folsom Stadium, Boulder, Colorado 80302.

Selected Publications from the National Science Teachers Association

FACILITIES FOR SECONDARY SCHOOL SCIENCE TEACHING: EVOLVING PATTERNS IN FACILITIES AND PROGRAMS (Hardcover 471-14636, Papercover 471-14638)

Discussions of evolving programs, pictures, diagrams, and descriptions of instructional areas and construction details provide practical ideas for everyone concerned with designing and remodeling space and with establishing patterns of science instruction. Based on a nationwide study of exemplary facilities conducted by the NSTA with support from the National Science Foundation. 1972. 173pp. Hardcover $15.00; Papercover $12.50.

INDIVIDUALIZED SCIENCE—LIKE IT IS (471-14634)

Sets forth the philosophy of individualized programs in science, describes five well-established programs, and offers suggestions for individualizing a single course or an entire program. Edited by Henry J. Triezenberg. 1972. 99pp. $3.50.

SCIENCE SELECTIONS (471-14632)

A compilation of short, newsy reports of current research in frontier areas of science. Compiled by the National Science Foundation staff. One copy is included with each loan or purchase of the NSTA minidocumentary films. Copies are also available for purchase in minimum lots of 5. 1971. 64pp. $0.20 per copy; minimum order, 5 copies (No discount).

MINIDOCUMENTARY FILMS

A series of 6- to 8-minute films on topics of current interest and concern in science. Originally prepared by the National Science Foundation for television and now available for educational use. Included with each film is a copy of *Science Selections* and a complete script of the film. 16 mm.

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Order at least two weeks in advance and give three choices of dates for each film. Enclose payment. Only orders on official purchase forms accepted for billing.

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VITAL VIEWS OF THE ENVIRONMENT (471-14604)

A compilation by Mary E. Hawkins of recent views of the environment, highlighting major concepts that illuminate environmental relationships. Included are statements by Frederick E. Smith, Garrett Hardin, Raymond F. Dasmann, Paul R. Ehrlich, René Dubos, and others. 1970. 32pp. $1.50.

ENVIRONMENTAL EDUCATION IN THE ELEMENTARY SCHOOL (471-14626)

A compilation by Sylvia K. Shugrue and Berenice G. Lamberton of articles about elementary environmental education from *Science and Children* 1966-1971, focuses on theories about environmental education, activities to reinforce environmental awareness, and actual programs of student participation in school beautification. 1972. 48pp. $2.75.

HELPING CHILDREN LEARN EARTH-SPACE SCIENCE (471-14606)

A selection of articles from *Science and Children*, 1964-1970, compiled by William H. Matthews III. Articles and brief suggestions in the areas of content, curriculum, and classroom ideas. Five major divisions: astronomy, geology, meteorology, oceanography and water, and conservation. 1971. 256pp. $5.00

HOW TO DO IT SERIES

This series of instructional aids is designed for use in elementary and secondary schools.

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SCIENCE LOOKS AT ITSELF

A selection of addresses from the NSTA Silver Year Symposia on the insights that science can bring to bear on some of today's crucial areas of public concern. With an Introduction by René Dubos. Published by Charles Scribner's Sons, New York. 1970. 125pp. $5.95.

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